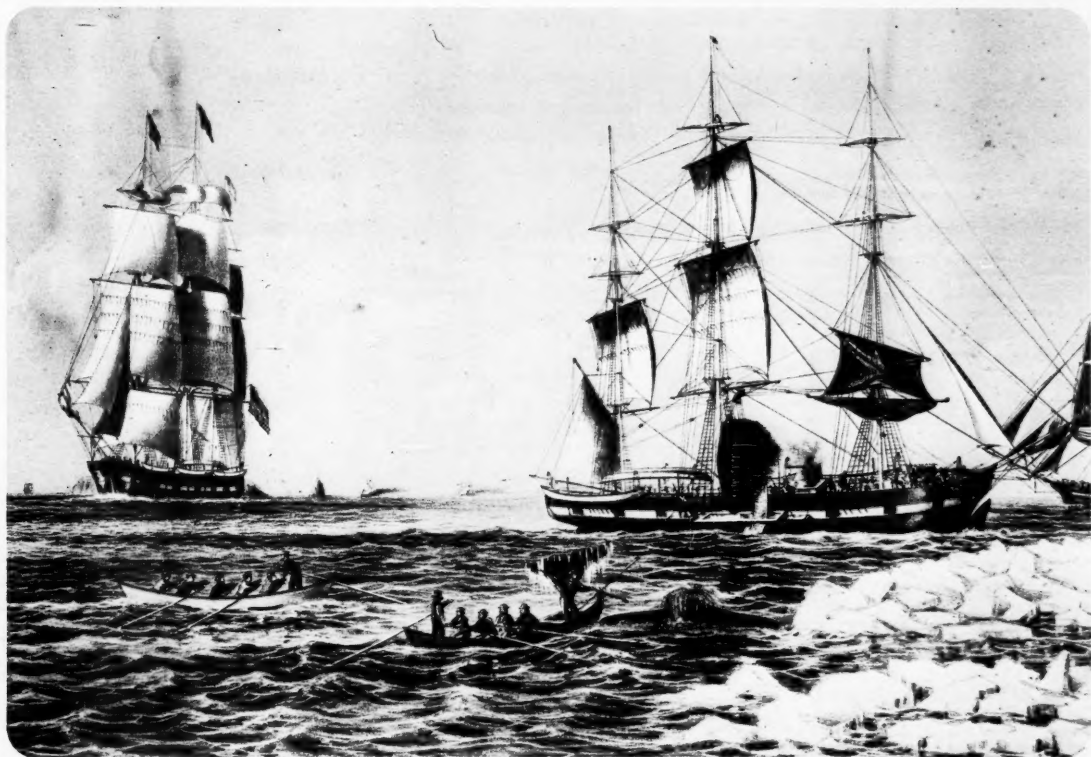




Marine Fisheries REVIEW

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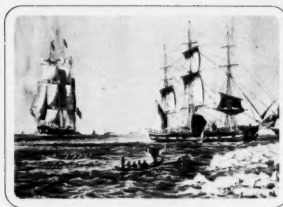


*The Bowhead Whale:
Whaling and Biological Research*

Marine Fisheries REVIEW



On the cover: Whaling in the Bering Strait and Arctic Ocean. Benjamin Russell lithograph courtesy of the Old Dartmouth Historical Society Whaling Museum, New Bedford, Massachusetts.



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The Bowhead Whale: Whaling and Biological Research

A Special Issue

Sponsored by the

National Marine Mammal Laboratory
Northwest and Alaska Fisheries Center
National Marine Fisheries Service, NOAA
Seattle, Washington

Editors:

Howard W. Braham
Willman M. Marquette
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J. Stephen Leatherwood

Preface

Bowhead whales, *Balaena mysticetus*, have been studied for centuries. Alaskan Eskimos studiously observed movements and behavior of bowheads, gaining knowledge that would help them hunt the whales in the shifting ice of spring and the turbulent waters of autumn. In 1848, the Eskimos were joined by outsiders, commercial whalers from the Yankee fleets to the south. Valued by these men for their great quantities of oil and baleen (or whalebone), bowheads were relentlessly pursued and were nearly exterminated. Fortunately, a few Yankee skippers recorded detailed observations, providing us with important information on the species.

In the past decade, scientific study of

the bowhead has burgeoned: In 1972 two scientists were studying the biology and habits of bowheads in the western Arctic Ocean and Bering Sea on a seasonal basis; by 1979 over 50 scientists were searching year-round for answers about this species.

This special issue of *Marine Fisheries Review* presents recent scientific findings, most from original research conducted since 1973. Scientists from western Europe, North America, and the U.S.S.R., as well as native Alaskan Eskimos, were invited to submit papers. Twenty-six authors representing 14 Federal, State, and private institutions responded. Seventeen papers are presented, beginning with an introduction to the problem which precipitated intensive study of the bowhead whale in 1978, followed by discussions of historical whaling, commercial and

subsistence, present population enumeration and estimates of the population size at the end of commercial exploitation, migration and distribution, behavior and sounds made by bowheads during migration, and, finally, biology of the bowhead whale. As incomplete a picture as they paint of this species, these papers constitute a significant contribution to our knowledge of the life history of the bowhead whale.

The editors wish to thank each author for cooperation in compiling this issue, as well as the many reviewers who provided needed assistance on short notice; their time is appreciated.

This issue is respectfully dedicated to the memory of Floyd E. Durham who passed away on 23 October 1980. We have lost a dedicated colleague and a good friend.

Introduction: A Scientific Perspective of the Bowhead Whale Problem

MICHAEL F. TILLMAN

Introduction

In June 1977 the International Whaling Commission (IWC) banned the hunt for bowhead whales, *Balaena mysticetus*, by Alaskan Eskimos. Although this species had been fully protected from commercial exploitation since the formation of IWC in 1947, a Native exemption had been in force since then which allowed a subsistence harvest. Deletion of this exemption fomented a crisis within the United States which has yet to be fully resolved.

At issue is whether the Federal Government can formulate a policy and a management regime which not only accommodate the cultural and subsistence needs of the Eskimos but also provide for the biological welfare of the bowhead whale, an endangered species. Developing an adequate plan has proved to be a difficult task with emotional confrontations occurring between those who espouse the cause of Native or human rights and those who are concerned with the conservation of whales. The inability to resolve this dilemma quickly has greatly reduced the effectiveness of the United States in fostering these two causes within the world community.

This paper contains a brief review of the historical, scientific, and legal background of the bowhead whale problem. The discussion is focused primarily on the research results upon which the IWC, rightly or wrongly, acted in 1977. By examining the state of knowledge up to that time, I intend to set the stage for the collection of papers contained in this special issue.

Life History and Stock Identity

The bowhead whale is one of the baleen or whalebone whales. The

common name refers to the whale's most distinctive feature: the strongly arched or bowed upper jaw which produces a distinctly shaped head and neck, in contrast with the fusiform shape of other whales. The head can measure up to one-third the total body length, and a full-grown animal can have 600 baleen plates in its mouth, the longest of which might be 427 cm (14 feet). A large whale could produce up to 1,452 kg (3,200 pounds) of baleen, which was worth as much as \$5 a pound during the heyday of Yankee whaling at the end of the 19th century.

Prior to exploitation, the bowhead whale was circumpolar in distribution, inhabiting Arctic and subarctic waters in four principal areas (Rice, 1977): Spitsbergen west to east Greenland; Davis Strait, Baffin Bay, James Bay, and adjacent waters, including Hudson Bay; Bering, Chukchi, and Beaufort Seas¹; and Okhotsk Sea. Due to excessive harvesting in the past, all populations are now thought to be seriously depressed (International Whaling Commission, 1978), and Jonsgaard² considers the Spitsbergen population to be extinct.

Of concern to the United States is the western Arctic bowhead population which occurs in waters extending from the Bering Sea in winter, to the northern Chukchi and Beaufort Seas in summer and autumn. The bowheads primarily

inhabit the loose pack ice and migrate with seasonal ice movements. Cracks or leads in the ice during spring form natural corridors through which the whales migrate and in which they are hunted by Eskimos.

Calving apparently occurs from late winter to early summer following a gestation of about 1 year. Mating behavior has been observed during the spring migration. Feeding apparently occurs during the summer and early autumn in shallow waters of the Beaufort and Chukchi Seas where the bowheads feed primarily upon euphausiids, copepods, and amphipods.

History of Utilization

According to Bockstoece³, Alaskan Eskimos have exploited the bowhead whale's nearshore migratory behavior for over 2,000 years; he estimated that prior to the influence of Yankee whalers, Eskimos were capable of taking 45-60 bowhead whales annually using traditional methods. Bowheads were hunted from boats covered with sealskin or walrus hides and were taken with harpoons to which were attached a series of sealskin floats. The floats impeded the whales' swimming and indicated their direction and points of reappearance at the surface. Whales were chased until exhausted and then killed with handheld lances.

During this era of traditional hunting the Eskimo used all parts of the whale for food and for tools, weapons, utensils, and toys (Carroll, 1976). Of course the most important parts of the whale, as in modern times, were the meat and muktuk (a layer of blubber with skin attached), providing protein, vitamins A, B, and D, and the large quantities of calories needed for Arctic survival.

The advent of Yankee whaling, however, completely altered the Eskimo's

¹In this issue of *Marine Fisheries Review*, the stock of bowhead whales inhabiting the Bering, Chukchi, and Beaufort Seas is designated the western Arctic population.

²Jonsgaard, A. 1979. Bowheads reported from the Spitsbergen-Barents Sea area in postwar years. Unpubl. document, IWC Panel Meeting of Experts on Aboriginal/Subsistence Whaling, Seattle, Washington, 5-9 February 1979, 3 p. Universitet i Oslo, Institutt for Marin Biologi og Limnologi, Postboks 1064, Blindern, Oslo 3, Norway.

³Bockstoece, J. 1976. Alaskan Eskimo shore whaling: Its impact on the bowhead whale, *Balaena mysticetus*, of the western Arctic. (Abstr.) Food Agric. Organ. U.N., Advis. Comm. Mar. Resour. Res., ACMRR/MM/SC/70, 1 p.

ancient way of life. Yankee whalers took their first bowhead whales in 1843 off the Kamchatka Peninsula in the Bering Sea and first sailed through the Bering Strait into the Arctic Ocean in 1848. News of the new, rich whaling ground spread quickly and by 1852 over 200 whalerships operated in the area (Bockstoe, 1978). Whale oil and, later, baleen were the main products taken. Oil was used as fuel for lamps and baleen was used by the fashion industry for, among other uses, "whalebone" corset stays and skirt hoops.

Starting in 1885 the nature of commercial whaling changed considerably. Shore-based whaling stations utilizing Eskimo crews were established and essentially eliminated traditional subsistence hunting. During this latter commercial period the Eskimos were introduced to Yankee technology, which included the darting gun and shoulder gun. These weapons fired small bombs whose detonation within a whale's body increased the likelihood of recovery.

By 1915 the commercial hunt for bowhead whales had ended, due to the decline of the population and a collapse of the "whalebone" market. Based on an analysis of historical whaling records, Bockstoe (1978) determined that over 19,000 bowheads were killed during 1848-1915. This figure accounts for the fact that a number of whales struck by harpoons or darting guns were not recovered but escaped and possibly died.

The Alaskan Eskimos subsequently returned to subsistence hunting. Only this time they were harvesting a severely depleted population and were armed with Yankee weapons.

Research Activities

Lack of Data Stimulates U.S. Research

Starting in 1972, the Scientific Committee of the IWC expressed concern about the lack of data on the status of the western Arctic bowhead population relative to the hunt by Alaskan Eskimos. In particular, no information had been provided by the United States on population abundance, on size of or trends in the subsistence catch, nor on

the number of whales which were struck and lost during the hunt.

Consequently, the National Marine Fisheries Service (NMFS) undertook research in 1973, focusing first on monitoring the harvest to determine the scope of the hunt, to gather basic harvest data, and to obtain biological samples from landed whales. This effort was expanded in 1976, through participation in NOAA's Outer Continental Shelf Environmental Assessment Program, to include censusing activities which would determine the bowhead population's distribution, migratory patterns, and indices of abundance.

Harvest Monitoring Results

Harvest monitoring by NMFS teams determined that in Alaskan waters, Eskimos hunt during the spring and autumn as the bowhead whales migrate past whaling villages. Residents of the two St. Lawrence Island villages, Gambell and Savoonga, and the mainland villages of Wales, Kivalina, Point Hope, Wainwright, and Barrow engage in spring whaling. Ice conditions east of Barrow do not permit spring whaling, but the eastern villages of Nuiqsut and Kaktovik, as well as Barrow, do participate in an autumn hunt.

Data on the number of bowhead whales struck and landed or struck but lost have been obtained directly by NMFS scientists since 1973¹. An extensive literature search has also been conducted to obtain data on the historical subsistence kill prior to 1973 (Marquette, 1979). The historical and recent harvest data are compared in Table 1. For 1915-69, the table presents 5-year averages of the total killed and landed, both spring and autumn, in all villages; data on the losses sustained during this period are incomplete. The last entry in the table is the 8-year average of recent data. Clearly, subsistence landings had increased through 1977.

A detailed examination of historical catch data reveals that between 1945

and 1969 the annual landings varied considerably but did not exceed 23 and averaged 10. Upon examining the recent data in detail (Table 2), one finds that in the 8 years, 1970-77, the annual landings exceeded 23 bowhead whales six times and averaged 30.

Table 2 also points out the problem of additional losses caused by the hunt. The information on whales struck but lost was obtained by interviewing Eskimo whaling captains and may be biased; i.e., some Eskimos, realizing the purpose of the interviews, may have underreported their strikes and losses. Despite these difficulties, a trend is obvious: Losses increased disproportionately as total landings increased. Whales that have been struck but lost present a problem since it is unknown how many have been injured severely enough to die.

Table 3 indicates that the number of

Table 1.—Average annual landings of bowhead whales by Alaskan Eskimos 1915-77¹.

Years	Average landings	Years	Average landings
1915-19	9	1945-49	9
1920-24	13	1950-54	10
1925-29	17	1955-59	7
1930-34	8	1960-64	13
1935-39	10	1965-69	12
1940-44	11	1970-77 ²	30

¹Source: Marquette (1979).

²Compared with average catch of 10 during 1945-69.

Table 2.—Landings and losses of bowhead whales by Alaskan Eskimos, 1970-77.

Season	Struck and landed	Struck but lost ¹	Total struck
1970	25	—	—
1971	24	—	—
1972	38	—	—
1973 ²	37	10	47
1974	20	31	51
1975 ³	15	28	43
1976	48	43	91
1977	29	82	111

¹Includes those known struck and killed but lost.

²NMFS monitoring began.

³Severe sea ice conditions occurred.

Table 3.—Number of Alaskan Eskimo crews participating in spring whaling at three major villages, 1971-77.

Season	Barrow	Point Hope	Wainwright	Total
1971	25	—	—	—
1972	27	—	—	—
1973 ¹	28	11	6	45
1974	21	10	2	33
1975	30	13	4	47
1976	36	14	8	58
1977	35	15	8	58

¹NMFS monitoring began.

¹Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-76, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

crews at three major whaling villages had generally increased through 1977. This trend could account for the observed increase in the take of bowhead whales and might be correlated to the exploitation of north slope petroleum resources starting in 1970 and the economic impacts of the Alaska Native Claims Settlement Act of 1971. The rising economic conditions of Eskimos apparently provided capital for new and inexperienced whaling captains to establish crews. According to Marquette (footnote 4), this inexperience as well as increased competition for whales apparently encouraged the use of poor whaling techniques. This state of affairs no doubt exacerbated the struck and lost problem inherent in the Eskimo hunts.

Needless to say, these trends of increasing landings, losses, and efforts, as well as the possibility of improper whaling practices alarmed the Scientific Committee of the IWC. In fact, concerned about the record high landings in 1976, the IWC (International Whaling Commission, 1977) passed a resolution recommending "... that contracting governments as early as possible take all feasible steps to limit expansion of the fishery and to reduce the loss rate of struck whales." The 1977 harvest data (Table 2) speak for themselves concerning the efficacy of U.S. actions in limiting the hunt that year.

Population Estimates

Results from censuses undertaken by the NMFS in 1976 and 1977 added to the IWC's growing concern over the status of the western Arctic population. During the spring, a camp was established each year on the ice next to the nearshore lead at Point Barrow. Depending on ice conditions, a team of observers attempted to maintain watch on a 24-hour basis to count all whales which passed by. Actual counts obtained were 352 whales in 1976 and 327 in 1977. Extrapolations of these data to account for the periods when no watch was possible gave abundance indices, respectively, of 762 and 715 whales (Braham et al., 1979).

These figures were not considered to be complete population estimates because it was thought that: Counters may

have missed some whales which swam by submerged; some whales may have migrated before and after the survey periods; some animals may have migrated through offshore leads; and some whales (perhaps females and calves) may have stayed behind in the Chukchi Sea. An additional source of error was that counters may have double-counted some whales passing by. Considering these possibilities, the Scientific Committee of the IWC believed that the counting data indicated a possible range of abundance of 600-2,000 whales (International Whaling Commission, 1978), with a best estimate of 1,300⁵.

Mitchell⁶ also presented an analysis of historical whaling data to the Scientific Committee's 1977 meeting which indicated that, during the peak period 1851-60, 8,852 bowhead whales had been taken in the western Arctic. Based upon a summary of published data on loss rates, he adjusted this cumulative catch by 24 percent to account for additional whales which were struck, lost, and died and obtained 11,700 as a minimum estimate of original population size. Adjusting for a residual component that contributed to the catch for an additional 20 years, he then obtained 18,000 as an upper bound for pre-exploitation estimates.

Comparing the best current estimate with these two pre-exploitation estimates indicated that the western Arctic population had declined to 7-11 percent of its original abundance. This apparent degree of endangerment plus the desultory results of the 1977 harvest prompted the Scientific Committee of the IWC (International Whaling Commission, 1978) to conclude that "... any taking of bowhead whales could adversely affect the stock and

contribute to preventing its eventual recovery, if in fact such recovery is still possible." Moreover, it recommended, and the IWC agreed, that "... on biological grounds exploitation of this species must cease ..."

Legal Background

In deciding how to respond to the IWC's action, the U.S. Government considered three pieces of domestic legislation. Under the Whaling Convention Act of 1949, which implemented U.S. participation in IWC, the Secretary of State, in concurrence with other departments, could within 90 days object formally to the IWC's ruling. Such an objection, which is allowed under the IWC's rules of operation, would allow the United States legally not to adhere to the ban. Otherwise, the Secretary of Commerce was authorized by this act to adopt regulations which would carry out the "purposes and objectives" of the IWC's regulations, including the ban.

The Marine Mammal Protection Act of 1972 (MMPA) and the Endangered Species Act of 1973 (ESA) both allowed aboriginal whaling to occur in U.S. waters under certain conditions. Under the MMPA, the subsistence hunt could not be accomplished in a wasteful manner and, if the population were determined to be depleted, the Secretary of Commerce could then prescribe protective regulations. Under the ESA, if it were demonstrated that the subsistence hunt materially and negatively affected the population, the Secretary of Commerce could again prescribe protective regulations. Both acts, however, required a rather lengthy and rigorous hearing procedure, as well as quite thorough proof that the circumstances warranted protective regulations.

Problem Resolution

The U.S. Government determined that a formal objection to the IWC would jeopardize its hard-won gains in fostering international conservation measures for the great whales. Furthermore, it decided that the most expeditious procedure for implementing regulations affecting the subsistence hunt was through the aegis of the Whaling Convention Act, since it did not require a formal hearing process. By

⁵Breiwick, J., and D. Chapman. 1977. Population analysis of the Alaska bowhead whale stock. Document SC/SPC/13, IWC Scientific Committee Special Meeting on North Pacific Sperm Whale Assessments, Cronulla, Australia, 21-26 November 1977, 5 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

⁶Mitchell, E. 1977. Initial population size of bowhead whale (*Balaena mysticetus*) stocks: Cumulative catch estimates. Document SC/29/33, IWC Scientific Committee Annual Meeting, Canberra, Australia, 6-24 June 1977, 113 p. Arctic Biological Station, Fisheries and Marine Service, Fisheries and Environment Canada, P.O. Box 400, Ste. Anne de Bellevue, Quebec, Canada H9X 3L6.

avoiding the long, arduous hearing procedure of the MMPA and ESA, the regulations needed to protect the bowhead whale could be implemented quickly. However, such rapid implementation ran the risk of abrogating the civil rights of Eskimos since they would be excluded from the decision making process.

Fortunately the circumstance of a special meeting of the IWC in December 1977, to reconsider the status of North Pacific sperm whales, gave the United States an opportunity to reopen the issue of the hunt for bowhead whales. Eskimo participation was obtained in developing a management proposal for submission to the IWC. The plan allowed a limited hunt with quotas on numbers struck as well as on numbers landed and promised to increase significantly the level of research undertaken⁷. Regulations for the hunt

were to be implemented and enforced through the Whaling Convention Act.

On reviewing the U.S. proposal, the IWC's Scientific Committee reiterated its findings that on biological grounds the hunt should not be allowed but recognized that the IWC might wish to consider subsistence or cultural needs which were beyond its expertise⁸. The IWC did consider these other aspects of the problem and finally agreed to remove the ban and to allow a take in 1978 of 12 whales landed or 18 struck, whichever occurred first.

This decision by the IWC established in 1978 the most ambitious U.S. research program ever devoted to a single species of large cetacean. As indicated by the following papers, dramatic results have already emanated from this effort. However, a far more encouraging aspect of the research program has been the willing participation by Es-

kimos in all of its phases. Such participation and cooperation must necessarily be the keynotes of any successful effort to balance the legitimate needs of both the Eskimo people and the bowhead whale.

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⁸International Whaling Commission. 1977. Report of the Scientific Committee Special Meeting: North Pacific Sperm Whale Assessments. Cronulla, Australia, 21-26 November 1977, 31 p. Int. Whaling Comm., The Red House, Station Road, Histon, Cambridge CB4 4NP, England.

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Historical Shore-Based Catch of Bowhead Whales in the Bering, Chukchi, and Beaufort Seas

WILLMAN M. MARQUETTE and JOHN R. BOCKSTOCE

Introduction

The Eskimos of northwestern Alaska have hunted the bowhead whale, *Balaena mysticetus*, since about A.D. 800, and there is archaeological evidence to suggest that the practice developed about 1,000 years earlier on St. Lawrence Island and the Siberian coast near the Bering Strait (Bockstoce, 1977; Fig. 1, 2). Whaling during an 8-week spring hunt and during a 4- to 8-week

autumn hunt at some villages provided the Eskimos with perhaps one-half of their winter food supply; until the 19th century, bowheads and Eskimos existed as co-inhabitants of a presumably stable ecosystem (Dunbar, 1953; Bockstoce, 1976).

In 1848, however, an event occurred that destroyed that stability. In that year a Yankee whaleman, Captain Thomas Roys of Sag Harbor, N.Y., discovered the rich bowhead whaling grounds

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north of the Bering Strait. Not only were the whales plentiful, but he found the bowheads to be slow, docile, and, most important, they had such a thick layer of blubber and great quantity of whalebone (baleen) that an average sized whale yielded 11,923 liters (100 barrels) of oil and 681 kg (1,500 pounds) of baleen (Bockstoce, 1980).

Word of Captain Roys' success spread quickly, and in 1852 more than 200 ships were operating in the Bering Strait region. The ice and weather took a terrible toll of ships and men, but the profits were worth the risk. The whalers continued to press farther north into the

Chukchi Sea, and eventually made their way into the Beaufort Sea where in 1889 they discovered the bowhead's feeding ground near the Mackenzie River Delta and Amundsen Gulf, Northwest Territories, Canada (Fig. 3).

It was baleen that eventually caused the near extinction of the western Arctic stock. After 1880 the demand for baleen grew as manufacturers increasingly came to value the flexible, resilient whalebone for use as corset stays, skirt hoops, and in umbrellas. At the beginning of this century the price of baleen rose to more than \$5/454 g (1 pound), making an adult bowhead worth more than \$10,000. The baleen was so valuable that the plates from an exceptionally large bowhead could pay all expenses of an Arctic cruise.

Although whaling vessels had systematically sailed the Bering and Chukchi Seas for 30 years, the Arctic Eskimos did not come into any significant contact with the whalers until after 1880 (Bockstoce, 1978). By that decade the increasing scarcity of the whales motivated the Pacific Steam Whaling Company of San Francisco, Calif., and other operators to establish shore-based stations along the Alaskan coast. This enabled the whalers to hunt bowheads in the early spring far in advance of the whaling fleet as the whales swam through open leads in the ice on their way to summer feeding grounds in the eastern Beaufort Sea. The venture was immediately successful and for a few years the number of whales killed increased, but this was short-lived (Bockstoce, 1978; Table 1, C-79).

During the 1880's the whalers found it more and more difficult to catch bowheads, and in response they began to press eastward past Point Barrow in pursuit of the migrating whales. For a short time in the 1880's the numbers of whales captured increased as steam powered vessels succeeded the slower and less maneuverable sailing ships. By the early 1900's, however, the number of whales taken again declined, for the population was now severely reduced. Their scarcity drove the price of baleen higher and higher, ultimately causing the industry to collapse in 1909 when spring steel began taking an increasing



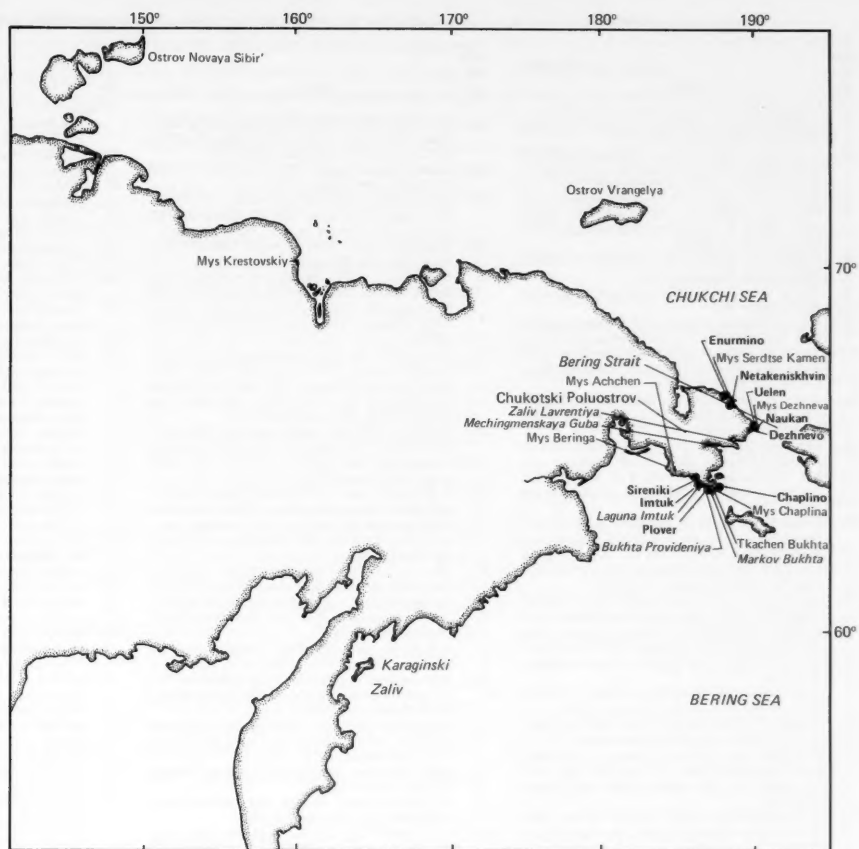
Figure 1.—Shore-based bowhead whaling sites on the Alaskan coast.

share of the market as a cheaper substitute for baleen.

Throughout the period of commercial exploitation Eskimos continued to take the bowhead for cultural and subsistence needs. After commercial whaling ceased, the Eskimo harvest continued at a relatively constant low level for 60 years. Beginning in 1970, however, Eskimo whaling effort steadily increased, as well as the number of whales taken; furthermore, the number of whales that had been struck but lost also greatly increased (Marquette, 1979).

Because of growing concern for the survival of this now rare and endangered species, the International Whaling Commission (IWC) in 1978 imposed an annual quota on the numbers of whales that could be landed or struck. Scientific determination of the status of this stock is hampered, however, by a paucity of data on the past catch of bowheads by whalers. The objective of this paper, therefore, is to provide a compilation of all known data on the historical catch of bowhead whales during shore-based operations along the coasts of the Bering, Chuk-

Figure 2.—Shore-based bowhead whaling sites on the U.S.S.R. coast.



chi, and Beaufort Seas. Analysis of the data and interrelated factors will be accomplished in a future report. Pelagic catch data, needed to complement an analysis of total take, are presented in a preliminary paper by Bockstoe (1980).

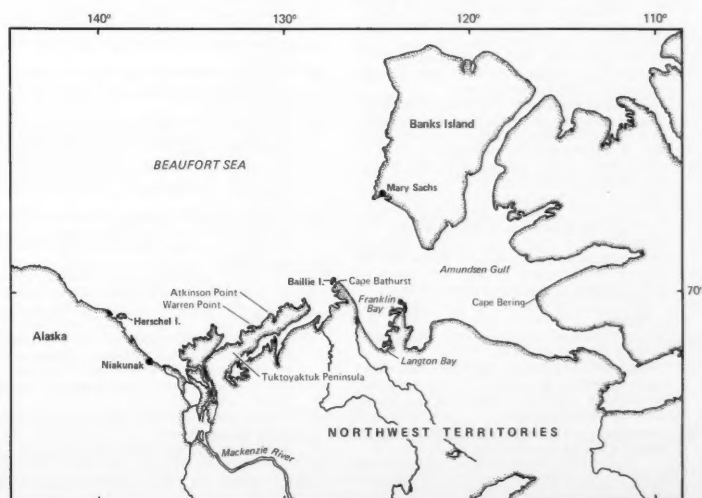


Figure 3.—Shore-based bowhead whaling sites on the Canadian coast.

Table 1.—Unpublished sources of data on whaling effort and the catch of bowhead whales by shore-based whalers in the western Arctic.

Code (C) no.	Source	Code (C) no.	Source	Code (C) no.	Source
1	Logbook Thomas Dickason, 29 June 1870. Providence Public Library, Providence, R.I.	29	F. A. Milan. (Department of Anthropology and Geography, University of Alaska, Fairbanks, AK 99701. Pers. commun. to Marquette, 19 April 1977).	55	Use Inventory. Commission on History and Culture, North Slope Borough, Barrow, AK 99723.
2	C. L. Hooper. Pers. commun. to William Windom, 14 June 1881. U.S. Revenue Cutter Service, Alaska File, R.G. 26, National Archives, Washington, D.C.	30	Journal Leo, 29 August 1879. Old Dartmouth Historical Society, New Bedford, Mass.	56	Logbook Montpelier, 6 August 1849. Providence Public Library, Providence, R.I.
3	Brower, C. D. 1863-1937. The northernmost American, an autobiography. Unpubl. manuscr., 3 vols., 895 p. Copy in Naval Arctic Research Laboratory library, Barrow, AK 99723.	31	U.S. Revenue Cutter Service, Alaska File, Refuge Station correspondence, R.G. 26, Microcopy 641/17 Frame 765, National Archives, Washington, D.C.	57	Logbook Betsy Williams, 7 July 1852. Kendall Whaling Museum, Sharon, Mass.
4	Logbook F.A. Barstow, 3 June 1891. Providence Public Library, Providence, R.I.	32	Logbook Mary and Helen, 12 August 1880. Old Dartmouth Historical Society, New Bedford, Mass.	58	Logbook George and Susan, 20 July 1859. New Bedford Free Public Library, New Bedford, Mass.
5	Journal Orca, 1 June 1891. Southampton Museum, Southampton, N.Y.	33	Sonnenfeld, J. 1956. Changes in subsistence among Barrow Eskimo. Unpubl. rep., 589 p. Arctic Institute of North America, Proj. No. CNR-140. Copy in Naval Arctic Research Laboratory library, Barrow, AK 99723.	59	Logbook Camilla, 4 July 1865. New Bedford Free Public Library, New Bedford, Mass.
6	Journal Belvedere, 23 July 1911. Private collection.	34	Rice, D. W. 1964. Eskimo whaling in Arctic Alaska. Unpubl. manuscr., 23 p. U.S. Fish Wildl. Serv., Bur. Commer. Fish. Avail. from Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.	60	I. Krupnik. Institute of Ethnography, Moscow, U.S.S.R. Pers. commun. to Bockstoeck.
7	F. H. Fay (Institute of Marine Science, University of Alaska, Fairbanks, AK 99701. Pers. commun. to Director, Mar. Mammal Div., Natl. Mar. Fish. Serv., Seattle, WA 98115, 9 October 1973).	35	D. W. Rice. (Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115. Pers. commun. to Marquette, 26 October 1979.)	61	Logbook John P. West, 21 June 1866. Mariners Museum, Newport News, Va.
8	C. J. Morgan (Institute for Environmental Studies, University of Washington FM-12, Seattle, WA 98195. Pers. commun. to Marquette, 25 July 1978).	36	R. K. Nelson. 1965. North Alaskan Eskimo exploitation of the sea ice environment. Unpubl. manuscr. Arctic Aeromedical Laboratory, Fort Wainwright, Alaska. Copy at Naval Arctic Research Laboratory library, Barrow, AK 99723.	62	Logbook John P. West, 12 July 1866. Mariners Museum, Newport News, Va.
9	Marquette, W. M. Harvest of bowhead whales by Alaskan Eskimos in 1973. Unpubl. manuscr. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.	37	Naval Arctic Research Laboratory (Staff). 1972. Eskimo whaling at Barrow, Alaska. Unpubl. rep., 24 p. Naval Arctic Research Laboratory, Barrow, AK 99723.	63	Journal Cornelius Howland, 23 June 1869. Providence Public Library, Providence, R.I.
10	Fiscus, C. H., and W. M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Processed rep., 23 p. Northwest Fisheries Center, Natl. Mar. Fish. Serv., NOAA, Seattle, WA 98115.	38	Journal Alexander, 5 July 1904. Dukes County Historical Society, Mass.	64	Logbook Fanny, 1871. Typescript 79-122. Old Dartmouth Historical Society, New Bedford, Mass.
11	Harry, G. Y., Jr. 1973. Arctic whales and the Eskimos. Unpubl. rep., 26 p., submitted as SC/25/Doc. 23 to the International Whaling Commission, London, June 1973, by Mar. Mammal Div., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.	39	C. D. Brower. 1886-1945. Diary. Copy in Naval Arctic Research Laboratory library, Barrow, AK 99723.	65	Logbook Northern Light, 27 June 1877. Old Dartmouth Historical Society, New Bedford, Mass.
12	G. A. Seaman (P.O. Box 80642, College, AK 99708. Pers. commun. to Marquette, 25 June 1976).	40	Logbook Orca, 26 July 1892. Private collection.	66	Logbook Mary and Helen, 23 May 1880. Old Dartmouth Historical Society, New Bedford, Mass.
13	Logbook Cornelius Howland, 5 July 1869. New Bedford Free Public Library, New Bedford, Mass.	41	Unidentified clipping, Scrapbook, Old Dartmouth Historical Society, New Bedford, Mass.	67	Logbook Thrasher, 22 May 1885. Private collection.
14	M. A. Healy. Pers. commun. to Secretary of the Treasury, 6 September 1888. U.S. Revenue Cutter Service, Alaska File, R.G. 26, National Archives, Washington, D.C.	42	Logbook Refuge Station, Barrow, Alaska; U.S. Revenue Cutter Service, Alaska File, R.G. 26, National Archives, Washington, D.C.	68	Logbook Francis Palmer, 3 July 1887. Kendall Whaling Museum, Sharon, Mass.
15	W. Howland. Pers. commun. to wife, 14 July 1890. Old Dartmouth Historical Society, New Bedford, MA 02740.	43	Logbook Mermad, 16 August 1896. Kendall Whaling Museum, Sharon, Mass.	69	Journal Orca, 1 June 1891. Southampton Museum, Southampton, N.Y.
16	D. C. Foote. (Geography Department, McGill University, Montreal, Que., Can. Pers. commun. to D. W. Rice, 2 November 1964, and records in Archives, Rasmussen Library, University of Alaska, Fairbanks).	44	Logbook Belvedere, 10 May 1898. Old Dartmouth Historical Society, New Bedford, Mass.	70	Logbook Belvedere, 11 May 1907. Kendall Whaling Museum, Sharon, Mass.
17	Journal Orca, 17 July 1891. Private collection.	45	O. C. Hamlet. Pers. commun. to the Secretary of the Treasury, 11 September 1906. U.S. Coast Guard, Historical Files of the Public Affairs Division, Washington, D.C.	71	Rosene Papers, Box 3, Archives Suzallo Library, University of Washington, Seattle, WA 98195.
18	Journal Orca, 21 July 1892. Private collection.	46	Logbook Belvedere, 25 July 1907. Kendall Whaling Museum, Sharon, Mass.	72	U.S.-U.S.S.R. Environmental Agreement, Section V: Marine Mammals Project, 1973 to present. Annual meetings with exchange of data on marine mammals in the Arctic. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.
19	Journal Mary D. Hume, 5 July 1893, Baker Library, Harvard University, Cambridge, Mass.	47	Logbook John and Winthrop, 29 July 1912. Private collection.	73	Bompas, W. The Esquimaux of the Mackenzie River. Unpubl. manuscr. Anglican Church Missionary Society, London, Engl.
20	M. A. Healy. Pers. commun. to Secretary of the Treasury, 25 September 1895. U.S. Revenue Cutter Service, Alaska File, Refuge Station correspondence, R.G. 26, National Archives, Washington, D.C.	48	Greist, M. 1968. Nursing under the north star. Private publ., Monticello, IN 47960 (copy in Monticello Public Library), 172 p.	74	Journal Narwhal, 10 August 1898. Dukes County Historical Society, Mass.
21	Edson. Pers. commun. to Board of Missions, 1 July 1896. Episcopal Church Historical Society, Austin, Tex.	49	F. E. Durham. (Los Angeles County Museum of Natural History, 900 Exposition Blvd., Los Angeles, CA 90007. Pers. commun. to Director, Mar. Mammal Div., Natl. Mar. Fish. Serv., 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115, 3 December 1972).	75	P. J. Usher (P. J. Usher Consulting Services, 185 Somerset Street W., Suite 309, Ottawa, Ontario, Can. K3P 0J2. Pers. commun. to Bockstoeck).
22	J. Driggs. Pers. commun. to Wood, 23 May 1902. Episcopal Church Historical Society, Austin, Tex.	50	Durham, F. E., and S. Burgess. 1972. Eskimo effort in bowhead whaling at Point Barrow, Alaska. Unpubl. manuscr., 19 p. University of Southern California, Los Angeles.	76	R. M. Gilmore (Natural History Museum, P.O. Box 1390, San Diego, CA 92112. Pers. commun. to Marquette, 8 April 1980).
23	Logbook William Baylies, 18 July 1906. Kendall Whaling Museum, Sharon, Mass.	51	F. E. Durham. (Los Angeles County Museum of Natural History, 900 Exposition Blvd., Los Angeles, CA 90007. Pers. commun. to Director, Mar. Mammal Div., Natl. Mar. Fish. Serv., 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115, 13 October 1972).	77	F. E. Durham (Los Angeles County Museum of Natural History, 900 Exposition Blvd., Los Angeles, CA 90007. Pers. commun. to Marquette, 27 February 1980).
24	Logbook William Baylies, 27 July 1907. Old Dartmouth Historical Society, New Bedford, Mass.	52	G. H. Jarrell. (Division of Life Sciences, Biological Sciences Program, University of Alaska, Fairbanks, AK 99701. Pers. commun. to Marquette, 11 October 1978).	78	Braham, H. W., B. Krogman, W. Marquette, D. Rugh, J. Johnson, J. Brueggeman, M. Dahlheim, M. Nerini, S. Savage, and R. Somnig. Research in the western Arctic on bowhead whales, June-December 1979. Unpubl. manuscr. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.
25	Logbook John and Winthrop, 16 July 1912. Private collection.	53	Journal Alexander, 25 May 1905. Dukes County Historical Society, Mass.	79	R. Barnes (Fisheries and Marine Service, Environment Canada, Inuvik, Northwest Territories, Canada X0E 0T0. Pers. commun. to Daniel O. Stewart, Natl. Mar. Fish. Serv., 632 Sixth Avenue, Anchorage, AK 99501, 15 December 1979).
26	Rev. H. Kinneveauk. (Point Hope, AK 99766. Pers. commun. to Marquette, 28 May 1976).	54	North Slope Borough. Beaufort Sea Traditional Land	80	Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (<i>Balaena mysticetus</i>) and beluga (<i>Delphinapterus leucas</i>) whales in the Bering, Chukchi, and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.
27	Durham, F. E. 1979. Recent trends in bowhead whaling by Eskimos in the western Arctic with emphasis on utilization. Center for Environmental Education, Inc., Washington, D.C., 53 p.				Marquette, W. M. 1977. The 1976 catch of bowhead whales (<i>Balaena mysticetus</i>) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.
28	Journal Mary and Helen II, 2 August 1886. Nantucket Historical Association, Nantucket, Mass.				

Evolution of Shore-Based Whaling

Shore-based bowhead whaling in the United States (State of Alaska) can be conveniently subdivided into three chronological phases of activity: aboriginal (before 1885), commercial (1885-1909), and subsistence (1910 to present). Similar phases of whaling activity also occurred along the shores of northwestern Canada and the Chukchi Peninsula of the Union of Soviet Socialist Republics (U.S.S.R.). However, because of the better documentation on shore-based whaling, only the Alaskan chronology is discussed in this paper.

Aboriginal Phase

Prior to making contact with the commercial whalers in the 1880's, Alaskan Eskimos hunted the bowhead using only primitive handcrafted equipment. Harpoons rigged with sealskin floats were used to slow the whale in its flight. When the exhausted animal could no longer flee, the hunters cautiously approached it and, after severing its tail tendons to prevent the whale from submerging, its chest cavity was repeatedly pierced with lances until it bled to death. Because the Yankee whalers were at first extremely wary of both the ice and Eskimos in the Arctic, records of contacts made between the two groups during this period provide scant information on the yearly catch of bowheads by the Eskimos.

Commercial Phase

In northwestern Alaska it was the establishment of shore-based whaling stations during the 1880's that marked the end of aboriginal whaling and the beginning of a commercial phase. Each station consisted of a building or native hut that housed a skeleton crew of Yankee whalers and their whaling equipment. Originally, one whaler was in charge of each boat, and he was assisted by five to seven Eskimos hired as crew members. As shore-based whaling prospered some stations employed all-Eskimo crews to man additional boats. Although the natives still needed whales for food, the baleen provided a market for their labor as crew members,

or, if they were hunting on their own, directly provided a saleable commodity. In both practices the result was the same: They received money or staple foods and manufactured goods in payment and, after the whaling station's crews had stripped the whales of their baleen, the carcasses were usually given to the Eskimos for food.

During the commercial phase the natives began to obtain darting and shoulder guns in trade from the whalers. These implements were developed by American whalers especially for quickly killing bowheads before they could escape among the protective ice floes. The darting gun was a small, smooth-bore weapon with a detachable harpoon fixed to the end of a wood shaft. It enabled the harpooner to shoot a small bomb into the whale at the instant he harpooned the animal. The bomb was designed to explode a few seconds later, deep inside the whale, causing instant death or injury sufficient to restrict its flight. The shoulder gun, usually of brass and weighing about 12 kg (27 pounds), fired a similar bomb through the air and was accurate to about 15 m (50 feet). It allowed the gunner to dispatch a wounded, potentially dangerous whale from a safe distance.

Subsistence Phase

Collapse of the whaling industry early in the 20th century ushered in the third phase in the history of shore-based whaling—a return to whaling as a subsistence activity. The Eskimos did not, however, return to the use of primitive whaling weapons that had been utilized during aboriginal times. Instead, they continued to use the darting and shoulder guns which greatly increased their hunting efficiency.

The subsistence phase, which began in 1910 and continues today, is separated into two periods marked by different levels of hunting effort and catch. From 1910 to 1969, whaling was characterized by a relatively low but steady level of activity. During 1970-77, however, a rapid increase occurred in hunting effort and in the numbers of whales taken and struck but lost (Marquette, 1979).

Methods

Sources of Data

Data on shore-based whaling in the Bering, Chukchi, and Beaufort Seas during the 19th and 20th centuries have been compiled by the authors for approximately a decade. Much of the information was obtained from unpublished sources (Table 1). Conflicting data occasionally were encountered, but these were resolved by selecting information from the source we judged most reliable. Also, some data which earlier were thought to be correct, when reported by Marquette (1979), required revision. Although the data presented are as complete as possible based upon information available to date, important gaps still exist in our records and we would appreciate comments from persons having additional information.

Eskimos traditionally have not kept a written record of their catches; at Barrow, however, the famous whaler and trader Charles Brower compiled a record of whales that he took from 1886 until the 1920's (Brower, 1942; Table 1, C-3). Brower's son David continued to record the catch from 1928 to 1960 (Sonnenfeld, 1960; Maher and Wilimovsky, 1963). At Point Hope early catch data from 1890 to 1948 were assembled by Foote (Table 1, C-16). Since 1949, a whaling record has been kept by Herbert Kinneveauk, a Point Hope whaler (Table 1, C-26). The remaining data used in this paper came from published and unpublished accounts by explorers, scientists, schoolteachers, nurses, adventurers, magazines, newspapers, church records, whalers' journals and logbooks, and personal communications with Eskimos and scientists who have visited whaling villages.

Recording of Data

Data on shore-based whaling along the coasts of the Bering, Chukchi, and Beaufort Seas is reported by country and includes the United States (State of Alaska, Fig. 1), U.S.S.R. (Fig. 2), and Canada (Fig. 3). Information on strandings of bowheads throughout these areas also have been included.

Information reported in this paper on shore whaling in Alaska includes yearly

statistics by village on: Numbers of whales landed, killed but lost, and struck but lost; numbers of crews whaling; and data sources (Table 2). In a few instances the yearly catch for some villages was reported as "a few," "some," or "several" whales had been caught, or that the natives had "a lot of baleen." To utilize this type of information it was necessary to use a figure representing an average amount for accounts of this type. Mayokok (1950) reported that in about 1915 there were "several" crews at Wales; Durham (1979) recorded an account of six crews at that village in about 1916. Allen (1978), neglecting to state how many whales had been caught, reported that "quite a lot" of whalebone had been taken at Point Hope in 1906; the log-book from the whaling vessel *William Baylies* (Table 1, C-23) recorded that nine whales had been taken there that year. Finally, Fraker et al. (1978) arbitrarily selected the amount of five to be used for all accounts of "several" bowhead whales reported as being sighted. Using these examples it was assumed that a quantity of five represented a reasonable amount to use in such cases; these estimated numbers are given in parentheses in the catch tables to separate them from the known catch¹.

Information on the numbers of crews whaling at all Alaskan villages has been compiled in an attempt to obtain some insight into the total effort expended annually by Eskimos for hunting bowhead whales (Table 2, Fig. 4). In most instances, the figures given represent a minimum number of crews because the total sum of active crews at a given village is seldom found in the literature. Occasionally it was possible to establish a specific number of crews whaling at some villages because the

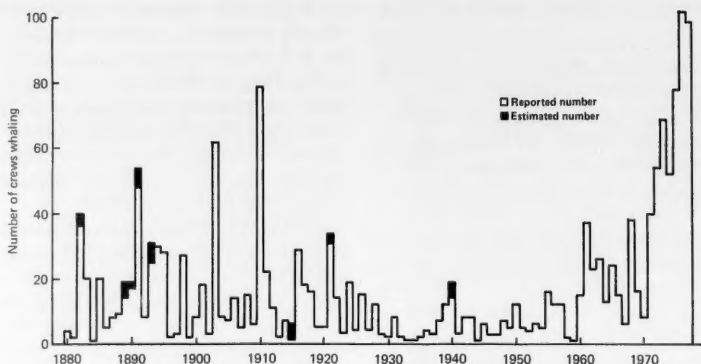


Figure 4.—Number of crews hunting bowhead whales yearly in Alaska. Because records are scarce, figures represent minimal numbers only to provide an index to whaling effort.

names of captains (crew leaders) that had successfully taken whales during a particular year were reported.

Additionally, information was collected on whales that had been struck but lost and those killed and lost. Numbers of individuals struck and lost have an as yet unquantified effect on estimates of mortality. Also, past reports on the bowhead catch frequently omitted those that had been killed but lost for various reasons. Since these incidents are important elements of total mortality, they have been recorded.

Information reported on shore-based whaling by Eskimos in the U.S.S.R. and Canada has been limited to the yearly catch of whales by village and data sources because of sparse data found on the other aspects of whaling.

Bowhead strandings in the Bering, Chukchi, and Beaufort Seas, including those found dead and beached, floating at sea, or frozen into the ice, are reported as they represent one aspect of total mortality within the population. This category includes whales that may have died as a result of whaling activities, e.g., those struck but lost. Although the fate of whales that have been struck but not retrieved is unknown, we do know that some individuals recover after being struck (Cook, 1926; Bodfish, 1936; Albert et al., 1980).

Results and Discussion

United States

Aboriginal Phase

Because of a paucity of information on aboriginal whaling, it is difficult to determine the numbers of whales harvested by Eskimos prior to 1885 when the commercial phase began (Table 2). Simpson (1854-55), who wintered at Barrow soon after the commencement of commercial whaling in the Bering Strait region, reported that the natives there killed 17 bowheads in 1852 and 7 in 1853. Although the 1852 catch was a successful harvest, 1853 was considered an extremely poor year, verging on disaster. Ray (1885) reported that 24 bowheads were landed at Barrow in 1854. During the period 1855-78, the available data indicate that five were taken at Point Hope in 1869, five at St. Lawrence Island in 1870, and four at Icy Cape in 1872. Murdoch (1885) noted that 10 bowheads were landed at Barrow in 1881. At Point Hope, village elders related to Rainey (1947) that their ancestors sometimes took as many as 15-18 whales during the spring season. From the available data, at least 8 or 10 whales per year were taken by the Alaskan Eskimos prior to 1884. This minimal estimate cannot be compared

¹The reader is advised that the authors could not come to a mutual agreement on the use of an estimated value for use in cases where the catch was given as a few, some, several, or a lot. The senior author therefore elected, for reasons stated, to use an average amount to facilitate presentation of such information in the tables and graphs. It is of course very possible that considerably more or perhaps fewer animals were taken, and the estimated values should be interpreted with care.

Table 2.—Data on shore-based bowhead whaling at sites in Alaska.

Number of whales						Sources (Literature cited and code (C) number in Table 1)	Number of whales						Sources (Literature cited and code (C) number in Table 1)
Site and year	No. of crews	Struck and lost	Landed	Killed but lost	Total killed		Site and year	No. of crews	Struck and lost	Landed	Killed but lost	Total killed	
St. Lawrence Island							Kivalina						
1870	—	—	5	—	5	C-1	1958	1	—	—	—	—	Morgan (1974)
1880	1	—	1	—	1	Keim (1969)	1960	1	—	—	—	—	Saario and Kessel (1966)
1881	—	—	1	—	1	Hooper (1881), C-2	1961	0	0	0	0	0	Saario and Kessel (1966)
1886	—	—	2	—	2	C-3	1964	—	—	1	—	1	Durham (1979)
1891	—	—	4	—	4	C-4, C-5	1970	—	—	1	0	1	Morgan (1974)
1894	—	(2) ¹	—	(2)	—	Cook (1926)	1971	—	—	1	0	1	Morgan (1974)
1899	—	—	1	—	1	Cook (1926)	1972	—	—	1	0	1	Morgan (1974)
1903	1	—	0	—	0	Cook (1926)	1973	—	—	0	1	1	Morgan (1974)
1909	—	—	0	—	0	Bodfish (1936)	1974	5	1	0	0	0	Morgan (1974), C-10
1911	—	—	3	—	3	C-6	1975	5	0	0	0	0	Marquette (1976)
1921	20	—	—	—	—	Hunt (1975)	1976	3	0	0	0	0	Marquette (1978)
1928	3	2	—	—	—	Geist (1937), Keim (1969)	1977	3	2	1	1	2	Marquette (1979)
1929	—	—	1	—	1	Keim (1969)	Point Hope						
1936	—	—	1	—	1	Smith (1937)	1869	—	—	(5) ²	—	(5)	C-13
1937	—	—	1	—	1	Smith (1937)	1880	—	—	5	—	5	Bean (1887), Hooper (1881)
1940	—	—	5	—	5	Hughes and Hughes (1960)	1882	8-10	—	—	—	—	Murdoch (1891)
1952	—	—	1	—	1	Rodahl (1963)	1885	10	—	12	—	12	Brower (1942), C-3
1953	—	1	2	—	2	C-7	1888	—	—	12	—	12	C-14
1954	—	—	0	—	0	Hughes and Hughes (1960)	1889	—	—	18	—	18	Poole (1971)
1955	11	—	2	—	2	Hughes and Hughes (1960), C-7	1890	1	—	1	—	1	C-3, C-15, C-16
1956	—	—	1	—	1	C-7	1891	8-10	—	8	—	8	Woolfe (1893), C-17
1957	—	—	0	—	0	C-7	1892	—	—	0	—	0	C-16, C-18
1958	—	—	0	—	0	C-7	1893	8-10	—	13	—	13	Woolfe (1893), C-19
1960	—	1	0	—	0	C-7	1894	—	—	3	—	3	Klengenberg (1932)
1961	—	1	1	—	1	Alaska* (1965), C-7	1895	—	—	0	—	0	C-20
1962	—	4	0	—	0	Alaska (1965), C-7	1896	—	—	33	—	33	C-16, C-21
1963	—	—	0	—	0	Alaska (1965)	1897	—	—	32	—	32	Eskimo (1897)
1964	—	—	0	—	0	Alaska (1965)	1898	—	—	2	—	2	Eskimo (1898)
1965	1	—	1	—	1	Alaska (1965)	1901	—	—	1	—	1	C-16, C-22
1966	2	—	2	—	2	C-8	1902	—	—	2	—	2	C-16, C-22
1967	—	—	3	—	3	Durham (1979)	1903	60	1	4	—	4	Allen (1978)
1968	20	4	1	—	1	Durham (1973), C-7	1904	4	—	1	—	1	Allen (1978)
1969	1	—	2	—	2	Alaska (1969b)	1905	1	—	2	—	2	Allen (1978)
1971	—	—	1	—	1	Durham (1979)	1906	1	—	9	—	9	C-23
1972	12	3	2	0	2	Burgess (1974)	1907	—	—	0	—	0	C-16, C-24
1973	20	1	6	—	6	C-9	1908	—	—	13	—	13	C-16
1974	11	2	2	—	2	Stevens (1976), C-10	1909	1	—	13	—	13	Marsh and Cobb (1910)
1975	23	—	1	—	1	Marquette (1976)	1910	22	—	1	—	1	Marsh and Cobb (1911), Allen (1978)
1976	22	5	8	0	8	Marquette (1978)	1911	—	—	3	—	3	C-16
1977	27	8	2	0	2	Marquette (1979)	1912	—	—	9	—	9	C-25
Wales							1913	—	—	1	—	1	C-16
1888	1	—	1	—	1	Ray (1975)	1914	—	—	2	—	2	C-16
1889	10-12	12	3	—	3	Thornton (1931)	1915	—	3	3	—	3	C-16
1890	10-12	2	0	0	0	Thornton (1931)	1916	—	1	7	—	7	C-16
1891	10-12	29	1	—	1	Thornton (1931)	1917	2	2	3	—	3	Reese (1918), C-16
1893	—	—	2	—	2	Eskimo Bull. (1893)	1918	—	—	7	—	7	C-16
1895	—	—	0	—	0	Ray (1975)	1919	—	—	2	—	2	C-16
1897	—	—	0	—	0	Eskimo Bull. (1897)	1920	—	—	3	—	3	C-16
1900	—	—	0	—	0	Bernardi (1912)	1921	—	—	2	—	2	C-16
1901	16	—	8	—	8	Eskimo (1936), Jackson (1906)	1922	—	—	13	—	13	C-16
1902	—	—	11	—	11	Witten (1904)	1923	—	—	1	—	1	Maykok (1955)
1906	—	—	0	—	0	Andrews (1939)	1924	14	1	16	—	16	Thomas (1962), C-16
1907	—	—	0	—	0	Andrews (1939)	1925	—	—	10	—	10	C-16
1908	—	—	0	—	0	Andrews (1939)	1926	—	—	13	—	13	C-16
1909	—	—	0	—	0	Andrews (1939)	1927	—	—	3	—	3	C-16
1910	—	—	0	—	0	Andrews (1939)	1931	—	—	1	—	1	Allen (1978)
1911	—	—	0	—	0	Andrews (1939)	1936	—	—	4	—	4	Eskimo (1937)
1912	—	—	0	—	0	Andrews (1939)	1940	10-15	8	5	—	5	Larsen and Rainey (1948), Rainey (1940)
1913	—	—	0	—	0	Andrews (1939)	1941	—	13	14	—	14	Alaska (1941, 1943)
1914	—	—	0	—	0	Eskimo (1916)	1945	—	—	3	—	3	C-16
1915	(5) ²	—	0	—	0	Andrews (1939), Maykok (1950)	1946	—	—	2	—	2	C-16
1916	6	—	1	—	1	Eskimo (1916), Durham (1979)	1947	—	—	6	—	6	C-16
1918	—	—	1	—	1	Eskimo (1918)	1948	—	—	0	—	0	C-16
1922	6	—	—	—	—	Bailey (1971)	1949	4	—	4	—	4	C-26
1938	1	—	1	—	1	Durham (1979)	1950	2	—	2	—	2	C-26
1939-68	—	—	0	—	0	U.S. Fed. Field Comm. (1968)	1951	4	8-10	4	—	4	C-16, C-26
1950	7	—	—	—	—	Mukluk Telegraph (1950)	1952	2	—	2	3	5	Weed (1957), C-26
1969	—	—	1	—	1	C-11	1953	4	—	4	—	4	C-26
1970	2	—	1	—	1	Durham (1979)	1954	3	—	3	—	3	C-26
1971	—	—	1	—	1	C-12	1955	1	—	1	—	1	VanStone (1962), C-26
1972	—	—	0	—	0	C-12	1956	9	3	2	—	2	VanStone (1962), C-26
1973	—	—	0	—	0	C-12	1957	3	—	3	—	3	C-26
1974	—	—	0	—	0	C-12	1958	1	—	2	—	2	C-26
1975	—	—	0	—	0	C-12	1959	1	—	1	—	1	Johnson et al. (1966), C-26
1976	2	0	0	0	0	Marquette (1978)	1960	13	8	4	—	4	Johnson et al. (1966), C-16, C-26
1977	2	0	0	0	0	Marquette (1979)	1961	13	2	2	—	2	Johnson et al. (1966), C-16, C-26

*The title of this magazine from the beginning of publication in 1935 through 1958 was *The Alaska Sportsman*, from 1959 through August 1969 it was *Alaska Sportsman*, and from September 1969 to the present it has been *Alaska*.

Table 2.—Continued.

Number of whales						Sources (Literature cited and code number in Table 1)	Number of whales						Sources (Literature cited and code number in Table 1)
Site and year	No. of crews	Struck and lost	Landed	Killed but lost	Total killed		Site and year	No. of crews	Struck and lost	Landed	Killed but lost	Total killed	
1962	5	1	6	—	6	C-16, C-26	1959	—	—	0	—	0	C-29
1963	3	5-6	3	—	3	Alaska (1963), C-26	1960	—	—	0	—	0	C-29
1964	1	—	1	—	1	C-26	1961	5	—	1	—	1	C-34, C-35
1965	11	—	2	—	2	Nelson (1969), C-26	1962	—	—	1	—	1	C-34
1966	5	—	5	—	5	C-26	1963	2	—	2	—	2	C-29
1967	1	—	1	—	1	C-26	1964	1	1	1	—	1	C-29, C-36
1968	3	—	3	—	3	C-26	1965	—	—	2	—	2	C-36
1969	2	18	3	—	3	C-26, C-27	1966	1	—	1	—	1	Nelson (1969), C-29
1970	4	7	8	3	11	Frankson (1970), C-26	1967	—	—	0	—	0	C-29
1971	10	3	6	—	6	Pederson (1971), C-26, C-27	1968	5	—	2	—	2	C-29
1972	12	—	14	—	14	Morgan (1972), C-26	1969	—	—	4	—	4	Durham (1979)
1973	11	—	7	—	7	C-9	1970	—	30	0	—	0	Durham (1979), C-27
1974	10	5	6	1	7	C-10	1971	2	—	2	—	2	Durham (1979), C-37
1975	13	13	4	0	4	Marquette (1976)	1972	—	—	2	—	2	Durham (1979)
1976	14	12	12	0	12	Marquette (1978)	1973	6	7	3	—	3	C-9, C-27
1977	15	11	2	0	2	Marquette (1979)	1974	2	—	1	—	1	C-10
							1975	4	—	0	—	0	Marquette (1976)
Point Lay							1976	8	3	3	0	3	Marquette (1978)
1886	—	—	6	—	6	C-28	1977	8	2	2	0	2	Marquette (1979)
1890	3	—	—	—	—	San Franc. Chron. (1890b)							
1930	1	—	1	—	1	Durham (1979)	Point Belcher and Point Franklin						
1939	1	—	1	—	1	C-29	1887	1	—	1	—	1	C-3
1940	1	—	1	—	1	Durham (1979)	1890	—	—	0	—	0	San Franc. Chron. (1890a)
							1891	—	—	1	—	1	C-3
Icy Cape							1892	1	—	0	—	0	C-3
1872	—	—	4	—	4	Pac. Commer. Advert. (1872)	1904	—	—	2	—	2	C-38
1879	—	—	1	—	1	C-30	1905	1	—	—	—	—	C-3
1887	—	—	0	—	0	C-3							
1890	1	—	—	—	—	C-3	Barrow						
1892	—	—	1	—	1	C-31	1838	20	—	—	—	—	Kashevarov (1838)
1908	—	10-12	—	10-12	—	Marsh and Cobb (1910)	1852	—	—	17	—	17	Simpson (1875)
1909	—	—	1	—	1	Marsh and Cobb (1910)	1853	—	—	7	—	7	Simpson (1875)
1910	1 ³	—	1	—	1	Durham (1979)	1854	—	—	24	—	24	Ray (1885)
1914	5	1	1	—	1	VanValin (1941)	1879	—	—	2	—	2	C-30
1916	6	—	—	—	—	Durham (1979)	1881	—	—	10	—	10	Murdoch (1885)
1917	3	—	3	—	3	Forrest (1937)	1882	20	(5) ²	1	—	1	Murdoch (1885, 1892)
1919	2	—	2	—	2	Durham (1979)	1883	20	(5) ²	2	—	2	Murdoch (1885, 1892)
1920	2	—	2	—	2	Durham (1979)	1884	—	—	10	—	10	Sonnenfeld (1960)
1921	2	—	2	—	2	Durham (1979)	1885	—	—	28	1	29	Murdoch (1892), C-3
1922	2	—	2	—	2	Durham (1979)	1886	3	—	—	—	—	C-3
1924	4	—	3	—	3	Durham (1979)	1887	6	2	22	—	22	C-39
1925	—	—	1	—	1	Andrews (1939)	1888	5	—	4	—	4	C-3
1926	—	—	1	—	1	Andrews (1939)	1889	7+(5) ²	1	28	—	28	San Franc. Chron. (1889), C-3
1938	1	—	2	—	2	Durham (1979)	1890	3	—	5	—	5	San Franc. Chron. (1890b), C-3
1939	1	—	1	—	1	Durham (1979)	1891	20	—	18	—	18	C-3
1940	2	—	1	—	1	Durham (1979)	1892	6	—	16	—	16	C-3, C-40
							1893	8-10	—	11	—	11	Woolfe (1893)
Wainwright							1894	28	—	43	—	43	C-3, C-41
1880	—	—	(5) ²	—	(5)	C-32	1895	28	—	9	1	10	C-3, C-42
1882	8-10	—	—	—	—	Murdoch (1891)	1896	1	—	7	—	7	C-3, C-43
1891	8-10	—	—	—	—	Woolfe (1893)	1897	1	—	5	—	5	C-3
1893	8-10	—	—	—	—	Woolfe (1893)	1898	13	—	38	—	38	Jarvis (1899), C-3, C-44
1916	3	—	1	—	1	Forrest (1937)	1899	1	—	(9) ⁴	—	(9)	C-3, C-39
1917	3	2	0	—	0	Eskimo (1917)	1900	8	—	20	—	20	Klengenberg (1932), C-3
1920	1	—	—	—	—	C-29	1901	—	—	(5) ²	—	(5)	C-3
1922	3	2	3	—	3	Bailey and Hendee (1926)	1902	—	—	(5) ²	—	(5)	C-3
1924	—	0	0	—	0	Andrews (1939)	1903	1	—	3	1	4	C-3
1925	—	2	—	—	2	Andrews (1939)	1904	4	—	2	—	2	Klengenberg (1932), C-3
1926	1	—	2	—	2	Andrews (1939), C-29	1905	4	—	5	—	5	C-3
1927	1	—	2	—	2	Allen (1978)	1906	13	—	8	—	8	Klengenberg (1932), C-45
1928	—	3	—	—	3	C-3	1907	5	—	9	—	9	Marsh and Cobb (1908), C-3, C-46
1931	6	—	6	—	6	Allen (1978)	1908	13	—	23	—	23	Marsh and Cobb (1910), C-3, Stefanon (1913)
1936	1	—	1	—	1	C-29							
1938	3	—	5	—	5	C-29	1909	3	—	11	—	11	Marsh and Cobb (1910), C-3
1940	—	0	0	—	0	Eskimo (1941)	1910	55	—	2+(5) ²	—	2+(5)	Marsh and Cobb (1911), C-3
1941	1	—	1	—	1	Alaska (1941), C-29	1911	20	—	1	—	1	Hadley (1915), C-47
1942	—	—	1	—	1	Sonnenfeld (1960)	1912	9	—	9	—	9	Hadley (1915), C-47
1943	—	—	1	—	1	Durham (1979)	1913	1	—	4	—	4	Evermann (1914), C-3
1944	—	2	—	—	2	Maier and Wilimovsky (1963)	1914	1	—	1+(5) ²	—	1+(5)	C-3
1945	3	—	6	—	6	C-29	1916	1	1	5	—	5	C-3
1946	1	—	1	—	1	Minner (1948), C-29	1917	9	—	7	—	7	U.S. Dep. Inter. (1917)
1947	1	—	1	—	1	C-29	1918	14	—	2+(7) ⁵	—	2+(7)	VanValin (1941), C-39
1948	6	—	—	—	—	Minner (1948)	1919	1	—	2	—	2	U.S. Dep. Inter. (1919), C-3
1949	—	2	—	—	2	C-29	1920	—	—	11	—	11	U.S. Dep. Inter. (1920)
1950	—	2	—	—	2	Maier and Wilimovsky (1963)	1921	6-9	—	—	—	—	C-48
1952	—	2	—	—	2	Bee and Hall (1956)	1922	1	—	1+(5) ²	—	1+(5)	C-3
1954	—	—	1	—	1	C-33	1923	1	—	2	—	2	C-3
1955	3	1	1	—	1	Milan (1964)	1924	—	—	5	—	5	Ostermann (1952), C-3
1956	—	—	2	—	2	Taber (1958)	1925	—	—	19	—	19	Richards (1949)
1957	—	—	0	—	0	C-29	1926	12	—	4	—	4	C-3
1958	—	—	0	—	0	C-29	1927	1	(5) ²	2	—	2	C-3

Table 2.—Continued.

Site and year	No. of crews	Number of whales				Sources (Literature cited and code (C) number in Table 1)	Site and year	No. of crews	Number of whales				Sources (Literature cited and code (C) number in Table 1)
		Struck and lost	Landed	Killed but lost	Total killed				Struck and lost	Landed	Killed but lost	Total killed	
1928	7	1	11	—	11	Mahe and Wilimovsky (1963), Vincent (1944), C-33	1975	30	10	10	1	11	Marquette (1976)
1929	—	—	15	—	15	Mahe and Wilimovsky (1963), C-33	1976	36	18	23	8	31	Marquette (1979)
1930	1	—	7	—	7	Mahe and Wilimovsky (1963), C-33	1977	35	56	20	2	22	Marquette (1979)
1931	1	—	11	—	11	Mahe and Wilimovsky (1963), C-33	Nulikut						
1932	2	—	7	—	7	Mahe and Wilimovsky (1963), C-37	1973	1	—	1	—	1	C-9
1933	—	—	5	—	5	Mahe and Wilimovsky (1963), C-3	1974	1	—	0	—	0	C-10
1934	—	—	4	—	4	Mahe and Wilimovsky (1963), C-33	1975	1	0	0	0	0	Marquette (1976)
1935	—	—	6	—	6	Mahe and Wilimovsky (1963), C-33	1976	3	0	0	0	0	Marquette (1978)
1936	—	—	4	—	4	Mahe and Wilimovsky (1963), C-33	1977	4	0	0	0	0	Marquette (1979)
1937	—	—	9	—	9	Mahe and Wilimovsky (1963), C-33	Kaktovik, Barter Island						
1938	—	—	4	—	4	Mahe and Wilimovsky (1963), C-33	1964	2	—	2	—	2	Durham (1979), C-51
1939	10	—	6	—	6	Mahe and Wilimovsky (1963), C-33, North (1940)	1972	—	—	1	—	1	C-52
1940	—	—	0	—	0	Mahe and Wilimovsky (1963), C-33	1973	2	—	3	—	3	C-9
1941	—	—	8	—	8	Alaska (1941)	1974	2	—	2	—	2	C-10
1942	7	—	10	—	10	Mahe and Wilimovsky (1963), Vincent (1944), C-33	1975	2	0	0	0	0	Marquette (1976)
1943	7	—	6	—	6	Mahe and Wilimovsky (1963), Vincent (1944), C-33	1976	7	0	2	—	2	Marquette (1978)
1944	—	—	0	—	0	Mahe and Wilimovsky (1963), C-33	1977	5	0	2	0	2	Marquette (1979)
1945	2	—	2	1	3	Mahe and Wilimovsky (1963), Buice (1947)	Miscellaneous Locations						
1946	1	—	9	—	9	Mahe and Wilimovsky (1963), C-33, Alaska (1947)	King Island						
1947	—	—	4	—	4	Mahe and Wilimovsky (1963), C-33	1897	—	—	1	—	1	Cook (1926)
1948	—	—	5	—	5	Mahe and Wilimovsky (1963), C-33	Little Diomed Island						
1949	—	—	0	—	0	Mahe and Wilimovsky (1963), C-33	1905	—	—	1	—	1	Jones (1927), C-53
1950	—	—	4	—	4	Mahe and Wilimovsky (1963), C-33	1910	—	—	1	—	1	Bodfish (1936)
1951	—	—	9	1	10	Mahe and Wilimovsky (1963), Spencer (1959), C-33	1916	11	—	1	—	1	Eide (1952)
1952	—	—	0	—	0	Mahe and Wilimovsky (1963), Spencer (1959), C-33	1976	7	—	—	—	—	Brummer (1977)
1953	1	—	17	—	17	Mahe and Wilimovsky (1963), Lindsay (1957), C-33	Kotzebue Sound						
1954	—	—	1	—	1	Mahe and Wilimovsky (1963), C-33	1880	—	—	1	—	1	Nelson and True (1887)
1955	—	(5) ²	19	—	19	Mahe and Wilimovsky (1963), Durham (1979), Freuchen and Salomonsen (1958)	Cape Lisburne						
1956	—	—	2	—	2	Mahe and Wilimovsky (1963)	1950	1	—	1	—	1	Durham (1979)
1957	9	—	0	—	0	Mahe and Wilimovsky (1963), Alaska (1957)	Cape Halkett						
1958	—	—	0	—	0	Mahe and Wilimovsky (1963)	1919	1	—	1	—	1	C-54
1959	—	—	0	—	0	Mahe and Wilimovsky (1963)	Cross Island/Prudhoe Bay						
1960	—	—	15	—	15	Mahe and Wilimovsky (1963)	1921	2	—	1	—	1	Carnahan (1979), Shapiro and Metzner (1979), C-54
1961	18	3	6	1	7	Caldwell and Caldwell (1966), C-35, C-37	1922	1	—	1	—	1	Carnahan (1979)
1962	17	2	5	1	6	C-35, C-49	1927	1	—	1	—	1	Carnahan (1979), C-54
1963	21	—	5	—	5	Groom (1963), C-37	1928	1	—	1	—	1	Carnahan (1979)
1964	7	6	11	—	11	C-27, C-37, C-49	1935	1	—	1	—	1	Shapiro and Metzner (1979)
1965	19	—	4	—	4	C-37, C-50	1938	1	—	1	—	1	Carnahan (1979)
1966	7	15	7	—	7	Foulter (1966), C-27, C-37	Flaxman Island						
1967	4	—	3	—	3	C-37, C-49	1929	1	—	1	—	1	Wentworth (1978)
1968	10	—	10	1	11	C-37	Unlocated						
1969	11	—	11	—	11	Morgan (1974), C-37	1898	13	—	—	—	—	Bertholf (1899)
1970	2	—	16	—	16	Alaska (1970), McVay (1973), Johnson (1977)	1916	—	—	1	—	1	Bower and Aller (1917)
1971	25	—	13	—	13	C-37, C-50	1917	—	—	2	—	2	Bower and Aller (1918)
1972	27	—	20	—	20	Okakok (1972), C-11, C-37	1923	—	—	2	—	2	Bower (1925)
1973	28	7	17	—	17	C-9	1937	—	—	6	—	6	Alaska (1938)
1974	21	20	9	2	11	C-10							

¹Natives reported to have about 2,000 pounds of baleen, assumed 2 bowheads taken. These estimated values are given in parentheses.

²For reports of a few, some, several, or a lot, an estimated value of five was assumed to be an average amount (see text and text footnote 1).

³Durham (1979) reported that as many as 11 crews whaled at Icy Cape.

⁴14,000 pounds of baleen reported, assumed 1,500 pounds per average large bowhead.

⁵10,000 pounds baleen plus two whales reported, assumed 1,500 pounds per average large bowhead.

with periods after 1884 when data are probably more complete and better represent the total annual catch by all whaling villages.

Commercial Phase

Shore-based commercial whaling began at Point Barrow in 1885 (Brower,

1942), and many other stations were soon established along the northwest coast of Alaska. By the winter of 1897-98, for example, 13 such stations, owned and operated by white men, were strung out along the coast between Point Hope and Cape Seppings (Bertholf, 1899; Fig. 1). These shore stations

thoroughly changed the character, but not the technique of Eskimo whaling. As many as 60 crews whaled at some stations in the spring (Allen, 1978), and most were made up of Eskimos from throughout northwestern Alaska. Before long, the number of crews operating had increased substantially above

the aboriginal level (Table 2). For example, shore-based commercial whalers more than tripled the number of Eskimo crews hunting at Point Hope prior to the establishment of whaling stations (Foote and Williamson, 1966).

The increased whaling effort during the commercial phase (1885-1909) is reflected in the increased take (Fig. 5). A total of 552 whales were taken during this 25-year period, resulting in an average annual catch of 22 animals. During this period an annual harvest of 38-49 whales occurred seven times. Although data gaps in the record mean that a total catch during the period cannot be determined, it appears likely that the harvest for some years exceeded 50 whales.

Subsistence Phase

Collapse of the commercial whaling industry in 1909 ushered in the third phase of Eskimo whaling—a return to whaling as a subsistence activity. Because bowheads were now commercially of little value, the number of Eskimo crews declined to near the aboriginal level as many native whalers turned to fur trapping as their only means of trading for manufactured goods. Trapping forced the Eskimos to leave the whaling villages and to disperse inland or along the coast. By 1914 the Alaskan Eskimos had almost abandoned whale hunting (Jenness, 1957). The incentive for whaling was so weak that in 1928 Brower (Table 1, C-3) remarked laconically that, although whaling conditions were good and whales were plentiful, many were bombed and lost because the Eskimos seemed to have forgotten how to whale and showed no interest in learning again because whalebone was now hardly worth taking.

During the period 1910-69, the annual catch dropped sharply, fluctuating between 1 and 25 animals except in 1925 when 32 were taken (Fig. 5). Years with high catches were relatively infrequent, exceeding 20 whales only seven times. During this 60-year period, the available records indicate a total of 704 bowheads were taken averaging 11.7 annually.

Beginning in 1970, however, the catch increased drastically (Fig. 5).

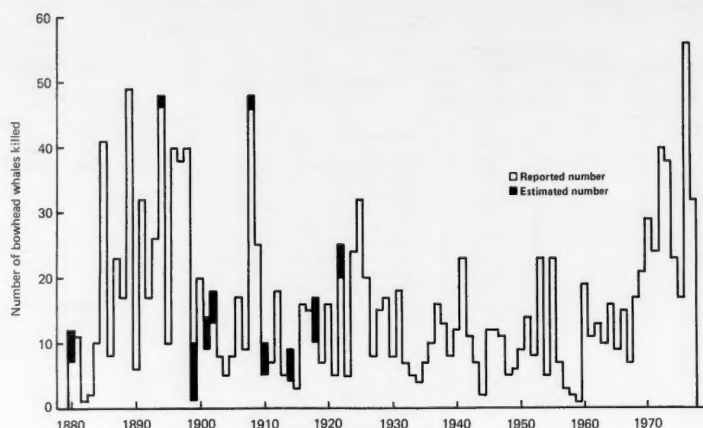


Figure 5.—Number of bowhead whales killed annually by shore-based whalers in Alaska.

From 1970 through 1977 a total of 259 bowheads, an annual average of 32.4 whales, were landed. This 8-year take alone consisted of 37 percent of the total taken during the previous 60 years. Since 1970, whaling effort during the spring season at Barrow has increased by more than 50 percent over the level during the 1960's, and a similar increase has occurred at St. Lawrence Island (Marquette, 1979; Table 1, C-80). A significant increase in effort has been recorded for the villages of Point Hope and Kivalina. In addition, there has been a marked increase in the number of crews hunting during the autumn at Kaktovik and Nuiqsut in recent years (Table 2). Beginning in 1978 the hunt has been on an annual quota basis established by the IWC; therefore, our study of the Alaskan catch concludes with the harvest for 1977.

U.S.S.R.

Whaling Villages

Little information is available on the locations where bowhead whales were taken by the Siberian Eskimos. Villages located on the Chukchi Peninsula (Fig. 2) are favorably situated for hunting bowheads during the spring and autumn migrations (Braham et al., 1980; Cook, 1926). However, because the animals

move beyond the area accessible to small whaling boats during the spring, the main whaling season is in the autumn (Tomilin, 1957). Tomilin (1957) stated that southbound migrating bowheads occasionally enter bays and inlets along the coast. In December 1933, for example, 2 bowheads were observed in Plover Bay and 10 were sighted in Tkachen Bay. Hunters at the village of Naukan in Bering Strait informed Tomilin that three to four times more whales were seen during the autumn than in the spring.

Eskimo hunters considered Mys Chaplina (also called Indian Point), across the Strait of Anadyr from St. Lawrence Island, to be the most productive place for whaling along the Chukchi Peninsula as it projects far out into the sea. Moreover, many large polynyas form there during ice covered periods. Tomilin (1957) also stated that natives residing along the north coast of the Chukchi Peninsula between Mys Dezhneva (also called East Cape) and Mys Serdtse-Kamen' seldom saw bowheads in the spring, but whaled primarily during the autumn; the catch was, however, poorer than that of Siberian Eskimos whaling in the Bering Strait. Zenkovich (1934) visited villages from Bukhta Provideniya (Providence Bay) to Mys Dezhneva in 1933

Table 3.—Number of bowheads landed by shore-based whalers at sites on the Chukchi Peninsula, U.S.S.R.

Year	Site						Chukchi Sea		Total	Source (Literature cited and code (C) number in Table 1)		
	Laguna Imtuk	Sireniki/Imtuk	Plover Bay	Markov Bukhta	Chaplino	Zaliv Lavrentiya	Naukan	Uelen			Netakenshvin/ Enurmino	Unlocated
1849	—	—	—	—	—	—	—	1	—	—	1	C-55
1851	—	—	—	—	—	—	—	1	—	—	1	Friend (1853)
1852	—	—	—	—	—	—	—	1	—	—	1	C-56
1859	—	—	4	—	—	—	—	—	—	—	4	C-57
1865	—	—	—	—	—	—	—	1	—	—	1	C-58
1866	—	3	5	—	—	—	—	1	—	—	9	C-59, C-60, C-61
1869	—	—	—	—	—	2	—	—	—	—	2	C-62
1870	—	—	(5) ¹	—	—	—	—	1	—	—	1+(5)	Nelson and True (1887), Wilkinson (1905)
1871	2	—	—	—	1	—	—	—	—	—	3	Wilkinson (1905), C-63
1877	—	—	—	—	—	—	—	5	—	—	5	C-64
1880	—	—	—	1	—	—	—	—	—	—	1	C-65
1884	—	—	—	—	5	—	—	—	—	—	5	C-66
1885	—	—	—	—	—	—	—	—	—	19	19	Bodfish (1936)
1886	—	—	(5) ¹	—	—	—	—	(5) ¹	—	—	(10)	C-3
1887	—	—	—	—	—	—	—	1	—	—	1	C-67
1891	—	—	0	—	—	—	—	—	—	—	0	C-68
1894	—	—	1	1	(1) ²	—	—	—	—	—	2+(1)	Russell (1898), C-59
1895	—	—	—	—	3	—	1	1	—	—	5	C-59
1898	(5) ¹	—	(4) ²	—	—	—	—	—	—	—	(9)	Cook (1926)
1899	—	—	—	—	1	1	—	1	—	—	3	Cook (1926), C-59
1900	1	—	1	—	—	—	—	—	—	1	3	Cook (1926), Crad (1939)
1902	2	—	—	—	—	—	—	—	—	—	2	Jones (1927)
1903	—	—	—	1	—	—	—	—	—	—	1	Jones (1927)
1906	3	—	—	—	—	—	—	—	—	—	3	C-69
1907	—	—	2	—	—	—	—	—	—	—	2	C-70
1908	1	—	—	1	—	—	—	7	2	—	11	C-59
1909	3	—	3	—	—	—	—	—	—	—	6	Bodfish (1936), C-70
1920	—	4	—	—	—	—	1	—	—	—	5	C-59
1924-32	—	—	—	—	—	—	—	—	6	—	6	Tomlin (1957)
1927	—	—	—	—	—	—	1	—	—	—	1	C-59
1928	—	2	—	—	—	—	—	—	—	—	2	C-59
1929	—	1	—	—	—	—	1	—	—	—	2	C-59
1930	—	1	—	—	—	—	—	—	—	—	1	C-59
1932	—	5	—	—	—	—	2	—	—	—	7	C-59
1933	—	6	—	—	—	—	2	—	—	—	8	Tomlin (1957), C-59
1934	—	6	—	—	—	—	2	—	—	—	8	C-59
1935	—	2	—	—	—	—	0	—	—	—	2	C-59
1936	—	0	—	—	—	—	3	—	—	—	3	C-59
1937	—	2	—	—	—	—	—	—	—	—	2	C-59
1958	—	1	—	—	—	—	—	—	—	—	1	Yablokov and Bel'kovich (1967)
1972	—	—	—	—	—	—	—	—	1	1	1	C-71
1973	—	—	—	—	—	—	—	—	2	2	2	C-71
1974	—	—	—	—	—	—	—	—	3	3	3	C-71
1975	—	—	—	—	—	—	—	—	2	2	2	C-71
1976	—	—	—	—	—	—	—	—	0	0	0	C-71
1977	—	—	—	—	—	—	—	—	0	0	0	C-71

¹For several, few, or some reported, an estimated value of five was used as an average (see text and text footnote 1). These estimated values are given in parentheses.

²Estimated from baleen obtained in trade from natives.

and reported finding hand harpoons with grenades (bombs) in native homes at Sireniki, Naukan, Dezhnevo, and Uelen (also called Whalen). In a later publication Zenkovich (1954) listed Chaplino as an important whaling village and stated that whaling also occurred at a few other (unnamed) locations. Sleptsov (1955) named Uelen, Sireniki, and Naukan as the principal whaling villages on the Chukchi Peninsula.

Whaling Activities

The catch of bowhead whales by Siberian Eskimos is poorly documented (Table 3). Tomlin (1957) noted that hunters at the villages of Netakenishvin and Enurmino caught only six whales between 1924 and 1932. He further stated that hunters along the northeast coast of the Chukchi Peninsula (presumably prior to 1955) took up to 10 whales annually using primitive

methods. Zenkovich (1934) stated that up to 10 bowheads were killed annually at villages from Bukhta Provideniya to Mys Dezhneva. According to Sleptsov (1955), 10-20 bowheads were taken annually at Uelen, Sireniki, and Naukan. Geller (1957) noted that whalers at the village of Naukan caught whale calves weighing up to 10,160 kg (10 long tons), and that "many" bowheads occurred in Mechigmen-skaya Guba (Mechigmen Bay) and were hunted by Eskimos using high powered rifles and firing up to 1,000 bullets during a single all-day hunt. Geller also stated that the local inhabitants avoided hunting humpback, *Megaptera novaeangliae*, and gray, *Eschrichtius robustus*, whales because they were too dangerous to pursue in small boats. Although Zimushko (1969) reported that bowheads were rarely taken by Siberian Eskimos, Ivashin et al. (1972) stated that during the more successful years they took up to 10 bowhead whales annually; unfortunately, no further details were given, such as time of year (presumably in autumn) or location.

Additional data on the early years of whaling by Siberian Eskimos has been provided by American authors. Information obtained from American whaling vessel logbooks and other whaling publications indicate that Eskimos inhabiting settlements at Zaliv Lavrentiya (St. Lawrence Bay), Mys Chaplina, Markov Bukhta (Marcus Bay), Plover Bay, Laguna Imtuk (also called John Howland Bay), Mys Achchen, and Mys Beringa (Cape Bering) hunted bowhead whales from May through October during early commercial whaling. Cook (1926), providing firsthand information, stated that Eskimos from Mys Dezhneva to Mys Chaplina on the west side of the Bering Strait, were very good hunters and, as the whales passed through the Strait in the spring and autumn, many were taken. Furthermore, he wrote that every settlement from Mys Dezhneva to John Howland Bay, a distance of about 232 km (125 n.mi.), was outfitted with boats and whaling gear obtained in trade with Yankee commercial whalers. Stefansson (1913) noted that a good many (number unspecified) bowheads were killed in the

spring by Siberian Eskimos at Mys Chaplina, Plover Bay, and at Mys Dezhnova. Foote (1966) wrote that Eskimos from at least one (unspecified) village on the Chukchi Peninsula were still hunting bowheads during the mid-1960's.

Catch Data

Insufficient data preclude a reliable estimate of the number of bowheads taken annually by Siberian Eskimos relative to the three major periods (aboriginal, commercial, and subsistence) of hunting. However, a rough estimate of the minimum annual harvest by decade is useful. From 1849 to 1859 the minimum mean annual take was 1.8 (Table 4). During the period 1860-1940, however, where the number of sample years was 38, no difference in catch by decade was noted (annual mean of 4.1). Apparently the annual take of bowhead whales did not vary greatly between the period when commercial whaling took place compared with the postcommercial or subsistence phase. Eight bowheads landed from 1972 to 1977 (annual mean of 1.3) were taken by means of U.S.S.R. gray whale catcher boats (Table 1, C-74). Siberian Eskimos have not hunted bowheads using traditional means since 1969 when chartered whaling vessels began to be used for taking gray whales to reduce the number of individuals struck but lost (Ivashin and Mineev, 1978; Zimushko and Ivashin, 1980).

Catch data for Siberian Eskimos are admittedly scarce, but the available information suggests that a relatively low harvest took place, perhaps 3-6 whales annually (Table 3). Since our findings indicate a lower annual catch than the approximately 10 whales reportedly taken annually in the Soviet literature, it appears that some significant records may be missing.

Whaling effort by Siberian Eskimos cannot be evaluated because of insufficient data. In 1887 and 1907, however, 35 and 20 crews, respectively, were reported whaling (Aldrich, 1889; Bodfish, 1936; Table 1, C-73). This suggests that a substantial effort was made relative to the catch (one whale in

Table 4.—Average number of bowhead whales landed by decade in the U.S.S.R. by Eskimos.

Ten-year periods	No. of years that catch is known	Total no. of whales landed	Average no. of whales landed (per year)
1849	1	1	1.0
1850-1859	3	6	2.0
1860-1869	3	12	4.0
1870-1879	3	14	4.7
1880-1889	4	17	4.2
1890-1899	5	20	4.0
1900-1909	7	28	4.0
1920-1929	5	16	3.2
1930-1939	7	31	4.4
1970-1979	6	8	1.3

Table 5.—Number of bowheads landed by shore-based whalers in northwest Canada.

Location	Year	No. of whales	Source (Literature cited and code (C))
Herschel Island	1888	1	Hadley (1915)
Niakunak	1918ca	1	Fraker (1977)
Between Cape Bathurst and Herschel Island	1915	1	Stefansson (1921)
Atkinson Point	1869	1	C-72
Baillie Island	1898	1	C-73
Baillie Island	1901	0	Cook (1926)
Baillie Island	1922	1	C-74

1887 and two in 1907) or that the catch data are underreported. Because the number of whales harvested each year can vary greatly even with near equal effort (Marquette, 1976, 1978, 1979; Braham et al., 1979; Table 1, C-80), comparisons of effort and catch are meaningless without more reliable documentation.

Canada

Whaling Activity and Catch

During the 19th century and first years of the 20th century, Eskimos in the western Canadian Arctic area hunted bowheads at Warren Point, Cape Bathurst, Langton Bay, and Franklin Bay (Maguire, 1857; Anderson, 1926, 1946; Fig. 3). After 1909, when baleen lost its commercial value, Eskimos continued to hunt bowheads only sporadically and occasionally may have killed one as late as the 1920's (Anderson, 1946; Fraker, 1977; Table 1, C-57). Regrettably, so few data have been found that a meaningful analysis of the Cana-

Table 6.—Bowhead whales found dead on the beach, frozen in the ice, or floating at sea in the Bering, Chukchi, and Beaufort Seas.

Location	Year	No. of whales	Sources (Lit. cited and code (C))
United States:			
Cape Beaufort	1826	1	Beechey (1832)
Pribilof Islands	1889	3	Jordan (1899)
Pitt Point	1913	1	Bailey and Hendee (1926), Allen (1978)
Prudhoe Bay	1913	1	Stefansson (1921)
Cape Halkett	1914	2	Jennens (1957)
St. Lawrence Is.	1931	1	C-75
Wales	1936	1	Collins (1937)
Kivalina	1951	1	Mukluk Telegraph (1951)
Little Diomedé Is.	1953	1	Carlson (1966)
Nome	1968	1	Alaska (1969a)
Barrow-Wainwright	1971	1	C-76
St. Lawrence Is.	1975	4	Fay (1975)
St. Lawrence Is.	1976	1	Fay et al. (1977)
Point Barrow	1976	2	Marquette (1978)
Point Barrow	1979	1	C-77
Canada:			
Herschel Is.	1894	1	Cook (1926)
Langton Bay	1905	1	Stefansson (1921)
Langton Bay	1910	1	"
Cape Bering	1911	1	"
Mary Sachs, Banks Is.	1914	1	"
Tuktoyaktuk Peninsula	1972	1	Kuyt (1974)
"	1973	1	Hoek (1978)
"	1974	5	Hoek (1978)
"	1975	3	Hoek (1978)
Herschel Is.	1978	2	C-78
Soviet Union:			
Uelen	1853	1	Holmes (1857)
Ostrov Vrangelya	1881	1	Hooper (1884)
Ostrov Novaya Sibir	1928	1	Tomlin (1957)
Karaginskii Zaliv	1932	(40-80) ¹	"
Uelen	1933ca	6	"
Mys Krestovskiy	1943	1	"

¹Reported that scores perished in the ice; we estimated 40-60.

dian Eskimo harvest in this area is impossible. Information located to date merely shows that from 1869 to 1922, six bowheads were taken by Eskimos along the Canadian coast of the Beaufort Sea (Table 5).

Strandings

Known bowhead strandings along the coasts of the Bering, Chukchi, and Beaufort Seas are listed in Table 6. These deaths may have resulted from any one or a combination of the following causes: 1) Natural mortality; 2) whales killed at sea by commercial whaling vessels and cast adrift after being stripped of their baleen; 3) whales that were struck but lost; or 4) accidental deaths, including entrapment in the ice. Strandings have been recorded

separately from the catch because it cannot be determined when death occurred or if the whales died as a result of whaling activities. Only a small number of strandings have been reported. This was probably more a result of a lack of interest in reporting such events rather than an actual indication of mortality other than catch data.

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A Preliminary Estimate of the Reduction of the Western Arctic Bowhead Whale Population by the Pelagic Whaling Industry: 1848-1915

JOHN BOCKSTOCE

Introduction

Today the bowhead whale, *Balaena mysticetus*, population of the Bering, Chukchi, and Beaufort Seas is at the center of a controversy about the effect of the Alaskan Eskimo hunt on its numbers. Although many observers believe the population has not recovered significantly from the low level at which it probably stood in 1915, hitherto no thorough attempt has been made to estimate the number of bowheads that were taken by the pelagic whaling industry. Based on primary resources (logbooks and maritime newspapers), this report presents the results of the first systematic endeavor to reach an estimate of the annual bowhead kill.

Although a few bowheads may have been taken between 1843 and 1847, these whales were not deliberately sought until 1848. In that year Captain Thomas Roys sailed into seas unknown to whalers and discovered the great whaling grounds beyond Bering Strait where the bowheads, oil-rich, baleen-laden, and docile, were found in numbers. Roys quickly filled his ship and returned to Honolulu to broadcast his success. Word of these new whaling grounds spread quickly, and in the following year more than 40 vessels sailed north and enjoyed equally successful cruises. In succeeding years the news of the 1849 season increasingly lured other vessels, and in 1852 more than 200 whale ships operated in the Bering Strait region¹.

The whalers quickly established a routine that they would vary only slightly for the next 60 years. Leaving New England in the autumn and rounding Cape Horn in the southern summer, they would fit out at Hawaiian ports or San Francisco, sailing for the Arctic in late March to reach the pack ice of the central Bering Sea a month later.

They took a few whales as they worked their way north toward Bering Strait through the melting floes, but by early June most of the whales had passed them and gone deep into the safety of the ice on the migration to their summer feeding grounds in the Arctic Ocean. The whalers would not see their quarry again until late July when the ice allowed the ships to approach the north coast of Alaska and intersect the whales traveling from the Beaufort Sea to their autumn feeding grounds near Herald Island in the Chukchi Sea. The ships often cruised near Herald Island until the violent weather and encroaching ice of early October drove them back to ports in the Pacific Ocean.

The whalers usually repeated these summer voyages once or twice more before returning to their home ports. Some alternated their summer hunts among cruises to the Arctic, the Okhotsk Sea, or the Gulf of Alaska, depending on where the best catches were being made; nevertheless, they rarely visited more than one of these areas per year.

The intensity of the hunting in the early years of the fishery quickly re-

duced the bowhead population. It is possible that the whales themselves responded to the threat for the catches of 1853 and 1854 were poor enough in comparison with previous years, and the fleet virtually abandoned the Bering Strait region in 1855, 1856, and 1857, turning its attention to the bowheads of the Okhotsk Sea. It too was soon overhunted, and the whalers returned to the Bering Strait in 1858 to cruise there regularly for the following half century.

In the spring, once the ships reached lat. 57° or 58°N, the whalers began to watch for bowheads; for the next 5 or 6 months they generally kept themselves in constant readiness to lower their boats. When they saw whales, if the seas were not too rough, four or five boats usually went after them. If the men were lucky, a boat got close enough to strike a whale with a harpoon. The whale would then run, towing the line and a boat after it and eventually becoming sufficiently exhausted so that it could be killed with a lance. But frequently whales escaped into the ice, towing lines and gear. In response to these losses the whalers, after about 1860, increasingly used darting guns (which were fixed to the harpoon shaft and fired a small bomb into the whale at the moment of striking) as well as shoulder guns (27-pound, brass, smooth bores that fired a similar bomb from a distance and thus generally replaced the lance).

Once the whale was dead, or if a dead whale were found, the carcass was towed to the ship, where the crew took the baleen aboard and stripped off and "tried out" (rendered into oil) the blubber. As a rough average, a moderate-sized bowhead yielded 100 barrels of oil (a barrel was 31.5 U.S. gallons) and 1,500 pounds of baleen.

By 1866 the hunting pressure had put the bowhead population in steep decline, and to offset poor catches the whalers began taking walrus, *Odobenus rosmarus*, and gray whales, *Eschrichtius robustus*, in the "middle season" between their spring and autumn encounters with the bowheads. A decline in oil prices soon ended this; by 1880 oil prices were so low that profits could only be made by taking baleen,

¹For the purposes of this report I define the Bering Strait region as the waters of the Bering and Chukchi Seas between approximately lat. 60° and 72°N.

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VESSEL'S NAME	NO.	MASTERS	AGENTS	SAILED	BOUND	LAST REPORT	OIL	VESSEL'S NAME	NO.	MASTERS	AG
New Bedford	310	Drew	Wm G E Pope	Aug 24, 52	N Pacific	Sept 18, 52, at Fayal	clean	New Bedford	276	Beetle	Charles I
Abigail	114	Pease	Abraham H Howland	Aug 18, 51	N Pacific	Nov 29, 52, at Maui	90 sp	John Andrews, b	353	James Arnold	Henry Ta
A H Howland	400	Norton	Abraham Barker	Sept 10, 50	N Pacific	Aug 52, in Bhering's sts wanting 1 wh		James Edw ar	434	R Lane, Jr	George F
Abm Barker	333	Morrison	Cook & Snow	June 1, 52	Indian Ocean	Aug 11, 52, at Fayal	landed 84 sp	Java	278	Lawrence	Geo & Ma
Active, bark	329	Carr	I Howland Jr & Co	Sept 21, 50	N Pacific	June, 52, off Cape Thadus	unk	Janus	325	Cornell	C R Tuck
Adeline	426	Cash	Isaac B Richmond	Sept 20, 52	Pacific			James Maury	336	Wheldon	Alexander
Addison	421	Ryan	John A Parker	June 11, 51	N Pacific	Aug 1, 52, off Bh'ngs sts 8 whs this sea		Jasper, bark	223	Rotch	Isaac B F
Alexander	381	Purinton	Jonathan Bouras Jr	Nov 13, 51	N Pacific	June 1, 52, in Bhering's sts 1 wh this sea		Jeannette	340	West	E Perry &
Alice Frasier, bk	406	Taber	Lemuel Kollock	Sept 10, 51	N Pacific	No date in Bhering's sts	8 whs	John Perry	436	Lawrence	Frederick
Alice Mandell	412	Wing	O R Tucker & Co	Sept 10, 51	N Pacific	Apr 19, 52, at Oahu for Arctic	60 sp	John A Parker b	342	Taber	James H
Alto, bark	236	Carr	Richmond & Wood	Sept 3, 51	Atlantic & ind	Abt Jan 4, 52, off River Platte	150 sp	John Howland	877	Taylor	James H
Alfred, sch	184	Gifford	Wm. G. E. Pope	June 12, 52	Atlantic	Sept 10, 52, at Fayal	landed 35 sp	John & Edward	318	Cathart	Wilcox &
Alfred Gibbs	482	Jones	Wood & Nye	Nov 13, 51	N Pacific	Aug 3, 52, off Oahu, bd n. 25 sp on bd		John Wells	368	Cross	Thos Kn
America	418	Flahar	I Howland Jr & Co	June 25, 51	N Pacific	Aug 1, 52, off Bh'ngs sts 6 whs this sea		Joseph Butler, b	192	Mayhew	George E
America, bark	357		Joseph A Bequais	In port		Arrived Oct 2, 52, 450 sp		Joseph Meigs	356	G Allen	Hathawa
Ametyst	340	Howes	John A Parker & Son	Sept 28, 50	Pacific	Aug 23, 52, at Tombez	700 sp	Julian	356	Cleveland	David R
Anaconda, bark	383		Isaac B Richmond	In port				Junior	378	Hammond	Swift & J
Anadir, bark	619	Swift	Swift & Perry	Jan 2, 51	N Pacific	Aug 21, 52, off Bh'ngs sts 8 whs this sea		J E Donnell, bk	343	Earl	James H
Andrews, bark	393	Nye	Wm F Howland	June 3, 50	Pacific	Sept 20, 52, at Tombez	900 sp	Kathleen, bark	312	Allen	David B
Antarctic	319	Bradbury	Wm F Howland	May 3, 52	Pacific	Sept 2, 52, at Fayal	landed 15 sp	Kensington	367	Clark	Henry F
Archer	322	Macomber	Edward W Howland	Oct 5, 52	Pacific	Sept 3, 52, at Fayal	landed 22 sp	Kutusoff	416	Pierce	I H Bart
Arnolds	360	Harding	James B Wood & Co	July 19, 52	Pacific	Sept 25, 52, old fm Fayal 440 sp landed		Lafayette, bark	341		F & G R
Atlantic, bark	367	Lace	Hathaway & Luce	Oct 31, 51	Atlantic & n	Sept 20, 52, at Tombez	1300 sp	Leticia, bark	275	Alden	John A I
Bulma	307	Dexter	J & J Howland	Sept 1, 49	Pacific	June 21, 52, lat 56 n. lon 172 w	unk	Lagoda	341	Toby	T & A R
Baltic, bark	396	Brooks	Alexander Gibbs	Nov 16, 51	N Pacific	Apr 9, 52, at Paita	200 sp on board	Lalla Rookh	323	Gardner	Almy
Barnstable	373	Coon	William P Dow	May 6, 51	Pacific	Aug 17, 52, at Fayal	landed 150 sp	Lancaster	383	Lakeman	Richmond
Barclay	281	Taber	Henry Taber & Co	July 7, 52	Atlantic	Aug 20, 52, off Bh'ngs sts 12 whs this sea		Lance	321	Clark	Russell
Bart Gonsold	336	Heurdis	I Howland Jr & Co	July 16, 51	Pacific	Early in season in Arctic had done well		Leonidas	376	Ellison	I H Bart
Benj. Tucker	249	Sands	O R Tucker & Co	Nov 5, 51	N Pacific	June 12, 52, off Johanna	640 sp	Levi Starbuck	376	Ellison	Benjamin
Beris, bark	214	Snell	Benjamin B Howard	June 4, 50	Indian Ocean	Arrived Sept 12, 52, 1000 sp 140 wh		Lewis	308	Clement	Abraham
Brandt	310		Alexander Gibbs	In port		Aug 22, in Bh'ngs sts	clean	Lexington, bark	201		Thomas
Brighton	354	Weaver	James D Thompson	Oct 9, 50	N Pacific	Aug 1, 52, off Bh'ngs sts 10 whs this sea		Liverpool	308	Barker	I Howla
Braganza	470	Devoll	Wm G E Pope	Sept 10, 50	N Pacific	Mch 14, 52, at Hilo	clean	Logan	297	Taber	T & A R
Bramm	246	Childs	Gideon Allen	Sept 9, 51	N Pacific	Sept, 52, at Fayal	clean	Louisiana	297	Taber	Swift &
Callao	324	Baker	Henry Taber & Co	July 27, 52	N Pacific	Mch 25, 52, at Maui	clean	Louisa, bark	316	Wyatt	James F
Cambria	362	Cott e	James B Wood & Co	Sept 3, 51	N Pacific	Last of July heard from	7 whs	L O Richmond	341	Cochran	Wm G I
California	338	Wood	I Howland Jr & Co	Oct 22, 51	N Pacific			Magnolia	366	G L Cox	Weston
Carolina	394	Gifford	William Gifford	Aug 3, 52	N Pacific			Malta, bark	161	Smith	S Thom
Carolina, bark	395		S Thomas & Co	In port		Sept 17, 52, lat 31 n. lon 42 w	clean	Manuel Ortiz, b	361	C H Cole	Jonath
Catalpa, bark	260	Hamblin	I Howland Jr & Co	Aug 12, 52	Atlantic & ind	Aug 1, 52, off Bh'ngs sts 5 whs this sea		Majestic	297	Percival	G R Tur
Canada	548	The West	Barton Ricketson	Oct 1, 51	N Pacific	Sept 14, 52, at Fayal	clean	Marango	426	Devoll	William
Canton	409	Wing	E Perry & W C N Swift	Aug 10, 52	N Pacific	Jan 7, 52, off Juan Fernandez	clean	Marcella, bark	210	Tounds	Reynold
Canton, 2d	280	Folger	O R Tucker & Co	July 31, 51	Pacific	Dec 26, 51, old at Oahu	30 sp 650 wh	Massachusetts	364	Bennett	Edward
Canton Packet	274	Howard	H H Bartlett & Son	Dec 28, 49	New Zealand	Apr 20, 52, off French Rock	900 sp	March, brig	89	Reynold	Rodney
Chas W Morgan	551	Sampson	Edward M Robinson	June 6, 49	Pacific	First of season heard from	unk	Margaret Scott	316	Wing	Samuel
Chandler Price	441	Taber	Wm G E Pope	July 25, 49	Pacific	May 27, 52, at Gallipagos	5500 sp 700 w	Marie, bark	207	Elridge	T & A I
Charles	290	Mancheste	Lemuel Kollock	July 25, 49	Pacific	Mch 20, 52, old fm Hong Kong	240 wh	Marie Theresia	330	Taylor	
Champion	184	Lewis	James D Thompson	June 18, 50	N Pacific	June 1, 52, off Seychelle Is	clean				
Chas Packet, bk	317	Haskins	Thos Knowles & Co	Apr 19, 51	Indian Ocean	Aug 28, 52, off Carol Island	900 sp				
Chas Frederick	317	Haskins	John A Parker & Son	Aug 28, 52	N Pacific	Mch 28, 52, at Maui	clean				

Figure 1. —Detail of page from *Whalemen's Shipping List*, 1852 (courtesy of New Bedford Whaling Museum).

the great flexible plates that hang from a bowhead's upper jaw and are used to filter food from the water. As the price of oil sank, forced down by petroleum products, the price of baleen began to rise dramatically, driven up by the call of the fashion industry for, among other uses, "whalebone" corset stays and skirt hoops.

In 1880 the western Arctic remained the major profitable whaling ground for the American fleet², and the rising price of baleen stimulated the development of steam-auxiliary whaling vessels. These

immediately proved successful in pursuing the whales to the least accessible corners of the Arctic Ocean. In 1889 steamers reached the bowheads' summer feeding grounds off the Mackenzie River delta in Canada's Northwest Territories, and from then until 1915 the focus of the industry was concentrated largely on those waters. Changes in fashion and the introduction of flexible spring steel as a cheap substitute for baleen caused the market to collapse in 1908, dragging the industry with it. After 1915, although a few vessels cleared port as whaleships, they were in fact primarily on fur trading and freighting voyages, and only a few whales were taken by ships thereafter.

Resources and Methods

The basic source for this study was the *Whalemen's Shipping List and Merchants' Transcript* (Fig. 1). Published in New Bedford from 1843 to 1914, it contains the most comprehensive documentation of the American whaling industry; weekly issues posted the latest information on all American whaling vessels throughout the world. The *Shipping List* (Fig. 2) was of particular use to this project because whaling vessels usually touched at a major port to refit, to take on fresh provisions, and to report their cargoes immediately before and after their half-year Arctic cruise; thus, their Arctic catch can usually be determined (expressed in barrels

²Vessels of other nations had ceased whaling there in the 1870's.

WHALEMEN'S SHIPPING LIST															YEAR 1852 PAGE 2 N.B.	
SEASON REPORT			SEASON REPORT			SEASON REPORT			SEASON REPORT			SEASON REPORT			WHALES	
SHIP	CAPTAIN	HOME PORT	SEASON	REPORT	WHALES	SEASON	REPORT	WHALES	SEASON	REPORT	WHALES	SEASON	REPORT	WHALES		
N.B. COLUMBIA	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. TUCKER	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. SANDS	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. BILGATON	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. VIGOR	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. BARKER	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. DEVILL	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. CALFONIA	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. WOOD	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. CITIEN	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. NORTON	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. CROSBY	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852
N.B. COMPER	Ref. B.S.	Whale	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852	1852

Figure 2. — One of the project's ledger sheets for New Bedford vessels, 1852 (courtesy of New Bedford Whaling Museum).

of oil and pounds of baleen) by subtracting the cumulative cargo listed in the spring from that listed in the autumn. Once in the Arctic, ships passing one another frequently reported their "season's catch" (usually expressed in the number of whales they had taken); this information, carried by ships leaving the Arctic, would also find its way to the pages of the *Shipping List*.

To organize these data I constructed a ledger sheet listing the following information from left to right: Column 1, the vessel's name, rig, captain, and home port; columns 2 through 4, successive seasonal reports; column 5, the postseason report; column 6, the pre-season report. This information was gathered for each year and subdivided by home port.

The data from the *Shipping List* were augmented and corrected by adding information from other newspapers (principally from Honolulu's *Friend* and Pacific Commercial Advertiser and several San Francisco papers) as well as from scattered data in more than 500 printed books, magazine articles, manuscripts, government documents, and logbooks. This body of data was then spot-checked for accuracy against in-

formation compiled in the nineteenth century by Dennis Wood, a New Bedford insurance broker³. These resources allowed me to expand my purview beyond the American whaling industry to include vessels of the other nations operating in the western Arctic: Hawaii, Germany, France, and Great Britain (Australia). In all, more than 14,000 reports were tabulated.

Of particular value was the information from logbooks and private journals (Fig. 3). After I had constructed the basic list of Arctic voyages from newspaper sources, I turned to the published checklists of the logbooks and journals that are now held in public collections. Using my list of Arctic voyages, I was thus able to identify the manuscript materials from this fishery. Of the more than 2,600 seasonal cruises, I found records of more than 600 in public collections. I then tried to examine a number of records equal to 5 to 10 percent of the Arctic cruises for each year. I extracted the following data from the logbooks and journals for each Arctic

cruise: The number of lowerings for whales, the number of whales struck-and-lost, the number found dead, and the number taken, as well as the names of ships seen in the Arctic and their reported catches. These data allowed me to expand and correct my list of Arctic voyages and to appraise a number of other aspects of the whale kill that varied from year to year throughout the duration of the fishery (see Discussion section).

The logbook data also provided me with information on the total number of bowheads taken during a vessel's Arctic season and the combined yield of oil and baleen from those whales. From this information I derived a cruise average for the size of the whales captured (expressed in barrels of oil and pounds of baleen); and using this average as a rough guideline, I applied it to the figure for the products of each ship's seasonal catch to estimate the number of bowheads taken by that ship.

When coupled with an understanding of the changing tactics and economics of the whaling industry, these averages proved to be a useful analytical tool for exposing spurious additions of oil or baleen. For instance, once the figures for a ship's oil and baleen had been divided by the appropriate year's average, (and if a wide discrepancy were found between the number of whales indicated by each [Fig. 2]), then a high oil figure from a voyage in the 1870's might indicate the presence of walrus oil or gray whale oil in the cargo. Similarly, in the 1890's (when the price of oil was very low) a high baleen figure frequently indicated that little oil was being saved.

A note should be made about the sources that I intentionally did not consult. A number of compendia of data about whaling voyages exist, but an examination of each revealed serious deficiencies for my needs. Although Starbuck's (1964) and Hegarty's (1959) important works were based on the information in the *Shipping List*, these authors included only the cumulative results of the entire whaling voyage and hence were of little value for determining the annual bowhead catch; further-

³Wood's records are held by the New Bedford Free Public Library.

1852 In the Arctic Ocean

Thursday August 13th Boring with cloudy weather and light breeze from P.E. the boat chasing whaley, the coxswain employed in setting up pipes. At 2 P.M. the mate fastened and at 4 P.M. we had him alongside when all hands went to dinner; at 4.30 began to cut in, first of us commenced a dead whale was discovered about 2 miles distant apparently not over 12 hours dead, two boats were immediately dispatched to secure him and tow to the ship, the balance of the crew then here in the first whale on their way by the watch when we made sail and stood with the ship for the other boat and whale, at 9 P.M. had him alongside near 9.40 commenced cutting, a ship in sight running down towards us. This is a glorious afternoon work at last 20th hours of ice in seven hours, and we can cheerfully say "all hail to the Arctic." Soon after we commenced cutting it set in a drizzling rain, we however persevered and finished in 3 hours and 12 minutes, when we had supper and at half past 1 A.M. the watch went down at 2 A.M. after the Captain's of Hagerman's whaley this season, after part took by the ship, leaving with her main yard aloft, hauling N. by E. wind N.W. the watch caught in boiling. We are now as far advanced to the North, that our compass will not traverse, and we are compelled to shake them every little while to make them run at all, there is also a strong current here setting to the Northwest which is evidently caused by the velocity of ice pressed toward the pole. The western sea is inhabited, clothes to hunt being scattered along by black, red, yellow

1852 In the Arctic Ocean

show as far up as 70 North, the location of the North Pole, according to the experiences of the different exploring expeditions in search of the N.W. passage, the current here however we do not think extends 30 miles from land, as we found ourselves at noon about 32 miles from land and had not been current at all.

No current here 24th Sept. by Ob. 67.28 N. Long. 171.25 W.

Friday August 14th Boring with foggy weather and light breeze from P.E. the ship hauling N.W. & and laying with main yard aback, the crew employed in boiling and setting up pipes. At 2 P.M. light up for a short time, saw a ship, two of them boiling also hauled forward and were ship hauling N.W. by N. middle part occupied by equally saw a whale the mate lowered and part of his boat's crew stored up the whale settled, at nearly saw upward of 20 ships, 16 of them boiling 2 cutting and the other whaling, after part midle clear, beautiful weather, and whaling in sight - lowered 1st 2nd and 3rd boats, did not, took at 9 the boat was called to the ship a light breeze on from the Eastward, the ship running for more whaley, in sight from west hauls in half an hour they hauled again, remained the day employed in boiling.

No current here 24th hours Sept. by Ob. 67.56 N. Long. 170.57 W.

Saturday August 15th Boring with fine weather and light breeze from the Eastward, plenty of whaley in sight, and boat chasing in every direction, each chasing their own whale.

Figure 3. — Journal of Montreal's 1852 cruise (courtesy of New Bedford Whaling Museum).

more there were some omissions and errors in each. Townsend (1935) devoted a section of his report to the bowhead whales of the North Pacific, but he segregated them neither geographically nor chronologically; consequently bowheads from the Okhotsk Sea and the western Arctic are listed together under the total number taken on an entire whaling voyage—not for each season. In addition, a spot-check of his data revealed that occasionally gray whales and right whales, *Balaena glacialis*, were counted as bowheads

and that some bowhead captures were overlooked. Although Clark (1887) listed seasonal reports for voyages to the western Arctic from 1868 to 1884, he omitted some vessels known to have operated there and included others that did not; his figures for each vessel's seasonal products frequently included walrus oil, gray whale oil, right whale oil and baleen, or bowhead baleen that was obtained in trade from the natives. Estimates of the bowhead kill that are based on these sources should be treated with skepticism.

Discussion

If the number of whales that a ship took in the Arctic was not recorded, then it was necessary to determine the average size of the whales taken in that year (expressed in barrels of oil and pounds of baleen) and then to apply this average to the ship's cargo of oil and baleen (Table 1). The averages were computed from information that was extracted from logbooks, journals, and those newspaper reports that included both the total number of whales taken

Table 1.—Preliminary information: Average size of whales taken.

Year ¹	No. of ship's returns used	Average size of whales taken	
		Oil (barrels ²)	Baleen (pounds)
1848	(12)	(132.43)	(1,644.06)
1849	12	132.43	(1,644.06)
1850	6	119.87	(1,644.06)
1851	9	117.04	(1,644.06)
1852	24	112.05	1,644.06
1853	11	113.07	(1,509.61)
1854	(11)	(113.07)	(1,509.61)
1855	(11)	(113.07)	(1,509.61)
1856	(6)	(97.74)	(1,516.12)
1857	(6)	(97.74)	(1,516.12)
1858	6	97.74	1,516.12
1859	16	111.21	1,469.69
1860	8	93.58	1,597.22
1861	5	113.33	1,733.33
1862	2	106.25	1,562.50
1863	6	106.17	1,419.75
1864	13	93.22	1,388.88
1865	13	98.13	1,526.08
1866	26	90.07	1,616.93
1867	30	86.95	1,383.06
1868	6	82.85	1,385.71
1869	22	88.20	1,464.00
1870	7	77.84	1,150.53
1871	(10)	(102.61)	(1,488.37)
1872	10	102.61	1,488.37
1873	4	95.90	1,568.18
1874	2	86.36	1,590.90
1875	6	97.09	1,327.27
1876	(6)	(97.09)	(1,327.27)
1877	2	125.00	1,568.18
1878	(5)	(118.05)	(1,527.77)
1879	5	118.05	1,527.77
1880	(5)	(118.05)	(1,527.77)
1881	(7)	(110.00)	(1,543.75)
1882	(7)	(110.00)	(1,543.75)
1883	7	110.00	1,543.75
1884	(11)	(96.98)	(1,149.31)
1885	11	96.98	1,149.31
1886	7	95.11	1,546.51
1887	9	91.70	1,403.25
1888	17	89.23	1,548.35
1889	13	83.17	1,403.57
1890	27	75.73	1,413.37
1891	20	88.97	1,212.02
1892	11	88.54	1,556.36
1893	8	86.95	1,521.73
1894	4	93.33	1,690.47
1895	3	92.50	1,260.00
1896	3	87.50	1,425.00
1897	3	122.33	1,461.11
1898	—	—	—
1899	5	102.08	1,503.21
1900	—	—	—
1901	—	—	—
1902	—	—	—
1903	—	—	—
1904	3	82.45	1,390.36
1905-15	—	—	—

¹If data is insufficient, another year's average, shown in parentheses, is used for further computations.

²One barrel is 31.5 U.S. gallons.

on an Arctic cruise and the amount of oil and baleen they yielded. Because these averages were obtained from a relatively small sample, I restricted their use to that of a rough guide and coupled them with other information (Resources and Methods section and Fig. 2) to estimate the number of whales taken by each vessel in a particular year. For those years in which insufficient data were available the average I used for computations was

Table 2.—Average catch and effort per vessel.

Year ¹	No. of logs consulted	Lowerings per vessel	Whales struck and lost per vessel	Whales found dead per vessel	Whales taken alive per vessel	Whales taken alive and dead per vessel ²	Percentage of alive whales to total catch	Effort: Lowerings per whale taken alive
1848	0	(30)	(1)	(0)	(11)	(11)	(100)	(2.72)
1849	1	30	1	0	11	11	100	2.72
1850	5	31	1	0	5	5	100	6.20
1851	11	22	3	1	7	8	87	3.14
1852	13	39	4	1	14	15	93	2.78
1853	7	34	3	2	5	7	71	6.80
1854	4	18	3	0	2	2	100	9.00
1855	2	41	3	0	4	4	100	10.00
1856	1	16	2	0	3	3	100	5.33
1857	1	(18)	0	1	(2)	3	66	8.00
1858	6	18	2	0	2	2	100	9.00
1859	5	19	2	0	3	3	100	6.33
1860	6	13	2	1	4	5	80	3.25
1861	3	15	1	0	6	6	100	2.50
1862	2	20	3	0	7	7	100	2.85
1863	5	27	2	0	14	14	100	1.92
1864	5	20	1	1	5	6	83	4.00
1865	6	24	2	1	7	8	87	3.42
1866	4	26	2	0	5	5	100	5.20
1867	4	27	1	0	8	8	100	3.37
1868	3	20	0	1	5	6	83	4.00
1869	7	21	1	1	9	10	90	2.33
1870	9	24	1	0	12	12	100	2.00
1871	6	11	1	0	3	3	100	3.66
1872	6	16	1	1	3	4	75	5.33
1873	4	14	1	0	3	3	100	4.66
1874	2	46	2	0	5	5	100	9.20
1875	4	15	1	0	9	9	100	1.66
1876	1	4	0	0	2	2	100	2.00
1877	3	23	2	0	9	9	100	2.55
1878	2	11	2	1	2	3	66	5.50
1879	1	27	9	2	7	9	77	3.85
1880	3	36	2	0	20	20	100	1.80
1881	1	33	0	0	17	17	100	1.94
1882	2	8	1	0	4	4	100	2.00
1883	2	7	0	0	2	2	100	3.50
1884	2	15	1	0	4	4	100	3.75
1885	4	20	2	0	6	6	100	3.33
1886	1	6	1	0	2	2	100	3.00
1887	2	30	1	0	6	6	100	5.00
1888	4	17	1	0	1	1	100	17.00
1889	3	8	0	0	1	1	100	8.00
1890	4	13	0	0	5	5	100	2.60
1891	5	16	1	0	6	6	100	2.66
1892	3	15	1	0	5	5	100	3.00
1893	4	11	0	0	5	5	100	2.20
1894	4	15	1	1	4	5	80	3.75
1895	4	17	1	0	4	4	100	4.25
1896	3	2	0	0	2	2	100	1.00
1897	3	19	1	0	5	5	100	3.80
1898	4	20	3	0	8	8	100	2.50
1899	3	24	0	0	15	15	100	1.60
1900	3	16	1	0	8	8	100	2.00
1901	3	6	0	1	3	4	75	2.00
1902	2	30	2	0	10	10	100	3.00
1903	2	19	1	0	5	5	100	3.80
1904	1	4	0	0	2	2	100	2.00
1905	2	18	2	1	8	9	88	2.25
1906	1	1	0	0	1	1	100	1.00
1907	1	16	1	0	5	5	100	3.20
1908	0	(16)	(1)	(0)	(5)	(5)	(100)	(3.20)
1909	1	5	0	0	2	2	100	2.50
1910	1	14	0	0	4	4	100	3.50
1911	2	18	1	0	7	7	100	2.57
1912	0	(18)	(1)	(0)	(7)	(7)	(100)	(2.57)
1913	0	(18)	(1)	(0)	(7)	(7)	(100)	(2.57)
1914	0	(18)	(1)	(0)	(7)	(7)	(100)	(2.57)
1915	0	(18)	(1)	(0)	(7)	(7)	(100)	(2.57)

¹If data is insufficient, another year's average, shown in parentheses, is used for further computations.

²This figure is the total of columns D and E in this table.

drawn from another year, close in time, with a reliable data base. For the years after 1897, when the total number of whales taken by each ship was frequently reported, it was often unnecessary to construct averages.

To determine the average annual catch and effort per vessel (Table 2), the following information was extracted from the logbooks: The number of times a ship lowered its boats to chase whales, the number of whales struck-

and-lost, the number found dead⁴, and the number taken alive. These data, in turn, allow an estimate of the effort expended per caught whale by computing the average number of lowerings per live whale taken. Because the technology of the fishery was altered somewhat with the introduction of steam auxiliary vessels, it would have been interesting to segregate these data into sail and steam categories; unfortunately the size of my data base would not allow me to do this with confidence. I plan to carry out such an analysis in a future project (see Future Research section).

Similarly, although it would have been desirable to collect information on the number of boats that were lowered during each encounter with whales (thus providing a better estimate of the effort per caught whale), this information rarely appears systematically in logbooks. It is likely that a larger body of data, collected with greater refinement, will allow this analysis (see Future Research section).

The information compiled in my ledgers yielded evidence of more than 2,600 whaling cruises to the Arctic. For the vast majority of these I was able to determine the amount of oil and baleen collected there and then to estimate the number of bowheads taken (Table 3) (see Sources and Methods section). The results of these computations appear in columns B and C of Table 3. I was, however, unable to determine the Arctic products of some of the ships; consequently I estimated their catches by using the figure for the average catch per vessel that we had established from logbooks and other reliable data (see Sources and Methods section and Table 2, column F). I estimated the annual total catch of whales (both alive and dead) taken by all known vessels (Table 3, column F) by combining the figures in Table 3, columns C and E. The estimated number of whales that were an-

Table 3.—Estimated number of whales taken and struck-and-lost by known vessels.

Year	Total no. of known vessels cruising in the Arctic	No. of known vessels with recorded products	Est. no. of whales taken ¹ by known vessels with recorded products	No. of known vessels without recorded products	Est. no. of whales taken ¹ by known vessels without recorded products ²	Est. no. of whales taken ¹ by all known vessels ³	Est. no. of whales struck and lost ⁴
	A	B	C	D	E	F	G
1848	1	1	15	0	0	15	1
1849	46	38	454	8	88	542	46
1850	110	94	1,358	16	80	1,438	110
1851	150	111	562½	39	312	874½	450
1852	220	211	2,585½	9	135	2,720½	880
1853	161	148	852½	13	91	943½	483
1854	42	35	78	7	14	92	126
1855	5	5	21	0	0	21	15
1856	13	13	49	0	0	49	26
1857	8	7	49	1	3	52	0
1858	101	99	442½	2	4	446½	202
1859	82	79	331	3	9	340	164
1860	47	46	267	1	5	272	94
1861	45	41	211	4	24	235	45
1862	17	16	111	1	7	118	51
1863	35	34	331	1	14	345	70
1864	80	77	373½	3	18	391½	80
1865	84	70	415	14	112	527	168
1866	78	77	660	1	5	665	156
1867	81	79	597	2	16	613	82
1868	59	58	458½	1	6	464½	0
1869	42	42	436	0	0	436	42
1870	54	53	601	1	12	613	54
1871	43	38	105	5	15	120	34
1872	34	31	196	3	12	208	32
1873	32	32	111½	0	5	116½	34
1874	17	16	134	1	5	139	20
1875	20	20	190	0	0	190	0
1876	19	18	140	1	2	142	44
1877	22	21	116½	1	9	125½	48
1878	24	13	43	11	33	76	261
1879	29	23	93	6	54	147	46
1880	23	20	252	3	60	312	0
1881	22	15	186½	7	119	305½	33
1882	34	31	177	3	12	189	0
1883	36	35	85	1	2	87	38
1884	38	35	174½	3	12	186½	82
1885	41	36	234	5	30	264	33
1886	33	32	161	1	2	163	37
1887	37	37	300	0	0	300	39
1888	39	36	147	3	3	150	0
1889	42	40	72	2	2	74	0
1890	39	37	133	2	10	143	35
1891	35	35	126½	0	0	126½	45
1892	45	44	243½	1	6	249½	313
1893	45	43	303	2	10	313	116
1894	33	32	111	1	5	116	30
1895	30	29	39	1	4	43	0
1896	26	25	91	1	2	93	24
1897	24	24	81	0	0	81	60
1898	20	20	152½	0	0	152½	109
1899	16	16	109	0	0	109	121
1900	16	11	81	5	40	121	42
1901	13	12	38	1	4	42	0
1902	12	12	68	0	0	68	24
1903	14	14	25	0	0	25	14
1904	17	17	57	0	0	57	0
1905	15	15	59	0	0	59	30
1906	14	14	25	0	0	25	0
1907	11	10	58	1	5	63	11
1908	10	10	25	0	0	25	10
1909	5	4	14	1	2	16	0
1910	4	4	8	0	0	18	0
1911	5	5	43	0	0	43	5
1912	4	1	2	3	24	26	4
1913	5	0	0	5	40	40	5
1914	4	2	11	2	14	25	4
1915	1	0	0	1	7	7	1

¹Whales taken both alive and dead.

²Based on average from Table 2, column F.

³Total of columns C and E, this table.

⁴Based on Table 2, column C.

⁴For the purposes of this report I have defined a struck-and-lost whale as one which could not be processed after being wounded, i.e., any live whale struck by a harpoon, darting gun, or bomb lance shoulder gun. Hence, any whale that was struck and lost and later found dead by a ship would be counted under the dead whale category. The very few whales that died of natural causes and were found by ships are also included in the dead whale category.

nually struck-and-lost (as defined for Table 2) was computed by applying the annual average (Table 2, column C) to the total number of known cruises in column A of Table 3.

A note must be made about the "half" whales listed in columns C and F of Table 3. Occasionally whaleboats from two ships would assist one another in capturing a whale; in such a case the

products would be shared, and, correspondingly, a mid-season report might list "7½ whales." If, in column F of Table 3, a year's total for the estimated number of whales taken by known vessels included a "half" whale, this fraction was rounded off to the next whole number for use in further computations because, of course, it represented one whale kill.

It is obvious that more whales were killed than merely those that were captured: Some wounded whales escaped and died; others were killed, sank, and could not be recovered; others were killed, taken to the ship, and then lost during gales before they could be processed. If it is assumed that 50 percent of the whales that were struck-and-lost (as defined for Table 2) died of their wounds, I have the estimated kill given in column F of Table 4. On the other hand, taking into account the losses referred to above, it may alternatively be assumed that 100 percent of those struck-and-lost are added to the figure for whales taken alive (this figure is shown in column G, Table 4).

My estimate of the number of whales taken by known vessels (Table 3, column F) included both whales captured alive and those found dead. Therefore, to reach an estimate of the total mortality, it was necessary to reduce this figure to an estimate of the number of whales taken alive (Table 4, column D) before adding to it the estimated number of whales that died after being struck-and-lost. It was necessary to group my data into six periods to allow a more reliable data base for computing the percentage of live whales taken to the total taken (Table 4, column C).

I estimate that I identified 98 percent of all pelagic whaling cruises⁵ to the Bering Strait region and western Arctic from 1848 to 1915. Thus, with 2,609 known cruises, it is likely that 2,662 cruises were actually made. If 17,597 whales were taken by those known vessels, and if between 18,759 and 21,020 whales were killed by known vessels, it is likely that between 19,142 and 21,448

⁵I am excluding vessels used solely for trading, shore whaling, freighting, walrusing, or wrecking, although some of these vessels cleared port as whalers.

Table 4.—Estimated number of whales killed by known vessels.

	No. of logs consulted	Est. no. of whales taken alive and dead ¹	Percentage of alive whales taken to total taken ²	Est. no. of whales taken alive ³	Est. no. of whales struck and lost ⁴	Lower est. of total mortality of whales by known vessels ⁵	Higher est. of total mortality of whales by known vessels ⁶
Year	A	B	C	D	E	F	G
1848-1859	56	7,536	91	6,858	2,503	8,110	9,361
1860-1869	45	4,068	94	3,824	788	4,218	4,612
1870-1879	37	1,873	95	1,779	570	2,064	2,349
1880-1889	24	2,032	99	2,012	308	2,166	2,320
1890-1899	37	1,428	97	1,385	227	1,499	1,612
1900-1915	19	660	97	640	124	702	764

¹Taken from Table 3, column F.

²Taken from logbook data.

³Taken from columns B and C.

⁴Taken from Table 3, column G.

⁵Number is equal to 50 percent of column E plus column D.

⁶Number is the sum of adjacent numbers in columns D and E.

whales were killed by all vessels (Table 5). Further research (see Future Research section) may well refine these estimates.

Future Research

This work should be considered a reconnaissance. To quickly assess the reduction of the western Arctic bowhead population, I restricted myself to using those resources that were both convenient and accurate. Out of the constraints of time and budget, I limited my logbook research to a representative sample, extracting data on a relatively coarse level.

In the future I plan to expand my data base and to refine my methods of data extraction through a project to be carried out in association with the Marine Biological Laboratory (Daniel B. Botkin, Co-principal Investigator), Woods Hole, Mass. We plan to build on the research I have begun here, using logbooks as our primary source, extracting daily information and storing it in a computer-based retrieval system, and organizing the information under a number of topics (including date, latitude and longitude, weather conditions, number of whales seen, and the size of whales captured).

Coupled with modern mathematical techniques and theories, these records can provide estimates of former stocks, relative changes in populations, popula-

Table 5.—Estimated number of whales taken and killed by all pelagic whaling vessels.

Item	No.
A Number of known cruises ¹	2,609
B Estimated total number of cruises ²	2,662
C Estimated number of whales taken by known vessels ³	17,597
D Estimated total number of whales taken ⁴	17,956
E Estimated number of whales killed by known vessels ⁵	50% rate: 18,759 100% rate: 21,020
F Estimated total number of whales killed by all vessels ⁶	50% rate: 19,142 100% rate: 21,448

¹Total of Table 3, column A.

²Assuming column A, this table represents 98 percent of all cruises.

³Total of Table 3, column F.

⁴Assuming column C, this table represents 98 percent of the total number.

⁵Totals of Table 4: column F (50 percent rate), assuming 50 percent of struck-and-lost whales died; and column G (100 percent rate), assuming 100 percent of struck-and-lost whales died.

⁶Assuming column E, this table represents 98 percent of all kills.

tion distribution, migration patterns, and the depletion of the whales. These data will allow development and verification of mathematical models of the bowhead population. Such models may be useful to gain insight into present and future population trends and into the requirements for the successful protection of this and other species.

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Minimal Historical Size of the Western Arctic Population of Bowhead Whales

L. L. EBERHARDT and J. M. BREIWK

Introduction

The present size of the bowhead whale, *Balaena mysticetus*, population inhabiting the Bering, Chukchi, and Beaufort Seas is estimated to be at least 2,000 individuals (Braham et al., 1979). Estimates of historical levels were obtained by Breiwick et al. (In press), who used estimates of removals since 1848 and a range of values of certain parameters to reconstruct population sizes.

Two sources of concern about the trend in stock sizes since the beginning of commercial exploitation in 1848 seem worth exploration. The first concern is that the heavy exploitation may have reduced the stock to such low levels that its genetic diversity is seri-

ously reduced. Commercial harvests effectively ended by about 1912 (Bockstoe, 1977); it is quite possible that the low point of the population occurred at about that time. If it is feasible to estimate a minimal population level, then such an estimate may permit evaluation of the issue of genetic diversity. The second concern is that the population may have continued to decrease since the cessation of commercial exploitation, due to a continuing take by Eskimos. The calculations that follow are intended to shed some light on these two sources of concern.

Materials and Methods

The basic idea is to start from the presumed low point of the population and assume a population size at that time. We then simulate the course of the growth of the population to the present, subject to available estimates of removals, and tabulate the outcomes of a number of individual simulations (500). By repeating this process with various parameter combinations, we

can suggest what sets of starting population sizes and parameters will result in populations in accord with the available recent estimates. The catch history used is that reported by Marquette and Bockstoe (1980), and the loss rates are those used in Breiwick et al. (In press).

Model

The underlying model parallels that of Breiwick et al. (In press), who assumed that the current population size could be modeled as:

$$P(t+1) = [P(t) - C(t)](1 - M) + R(t) \quad (1)$$

where $P(t+1)$ represents the current population size, which is equal to that of 1 year ago less the removals $[C(t)]$, reduced by mortality $[\exp(-M)]$ approximately equals $1 - M$, and increased by recruitment $[R(t)]$. Recruitment depends on population size T years before, reproductive rate, and survival to the present. Hence,

$$R(t) = rP(t-T) \quad (2)$$

Because very little is known about these parameters in bowhead whales, the only course open at present is to assume a recruitment rate and a "lag" period. The lag period (T) is inserted to reflect the fact that current births depend substantially on the size of the population some years back; i.e., reproduction is a function of the mature

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members in the population. The use of the lag term does not imply that younger animals are assumed not to be part of the population for some period of time. We thus assume two parameters (net recruitment rate [$r-M$] and lag time) and vary these parameters over a range of values. The net recruitment rate is taken as ranging from 0.01 to 0.05, and the lag period is taken as 0, 5, or 7 years.

Breiwick et al. (In press) assumed a logistic model for the behavior of net recruitment (varying as a function of population size). We do not include that assumption here, on the grounds that it would not be of any importance at the current low level of the population. We assume the natural mortality rate (M) to be 0.05 or 0.07. The above parameter values are essentially those used by Breiwick et al. (In press), except that they used a wider range of mortality values. Their results showed that natural mortality is the least sensitive of the parameters considered.

Calculations

The calculations were carried out on a CDC 6400/CYBER 173 computer¹. The model was as given in Equation (1), but stochastic elements were incorporated by approximating the expected variation in survival from year to year by a random draw from a pseudonormal (Naylor et al., 1968) population with mean zero, and binomial variance depending on current population size. That is, we calculate $\text{var}(M) = M(1-M)/P(t)$. A similar draw was made for recruitment, for which the variance was assumed to be Poisson and equal to the current net recruitment. Each calculated population size was rounded to the nearest integer.

The year 1912 was used as the start of calculations because this appeared to be approximately the time of the minimum in the population trajectories determined by Breiwick et al. (In press). The choice of 1912 is also supported by the exploitation record, as the last substantial commercial harvest was carried out

in 1911 (Marquette and Bockstoe, 1980).

Results

An example of the outcomes of the simulations appears in Figure 1, which shows the frequency distribution of the 1978 population for an initial population of 700 (in 1912), at various values of net recruitment ($r-M$). Note that the frequency distributions progressively spread wider with increasing net recruitment.

Tables 1 and 2 present the mean values of each simulation, tabulated according to the initial population size (1912), and values of ($r-M$), the net recruitment rate. Each of the net recruitment rate values is further subdivided by three lag periods. A comparison of individual entries in the two tables shows that the effect of postulating different overall mortality rates (M) is of minor importance. Also, lags of 5 or 7 years yield much the same results, while the absence of a lag period does result in a substantially higher simulated 1978 population. The main utility of the results is to show which 1912 population sizes would result in 1978 population sizes that are of the same order of presently available estimates, i.e., are at least 2,000 animals. Reference to Figure 1 will provide a notion of the "spread" about the mean values for various values of net recruitment ($r-M$).

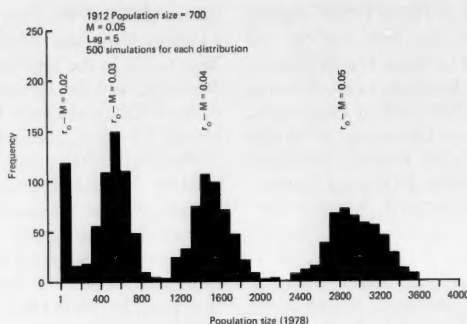


Figure 1.—Frequency distributions of 1978 population of bowhead whales for a 1912 population of 700 and various rates of net recruitment (500 computer simulations were used for each distribution).

An inspection of the tables will show that a population of 2,000 or more animals in 1978 is unlikely to have resulted if the 1912 population were less than 600 or 700 individuals, under the conditions of the simulations. Also, it seems evident that a fairly high net recruitment rate would be required to achieve current population levels on the order of 2,000 if the 1912 population were much less than 1,000 whales.

Discussion

The main conclusion supported by the simulations is that, under the present model and data, there is little reason to suppose that the 1912 population was less than 600 individuals. We expect that further refinements in the estimated catch will tend to drive the lower limit on the 1912 population upwards. The evidence does not support concern about an impact of population size on genetic diversity.

It seems to us quite unlikely that the 1912 population was greater than the present population level. If this were the case, then we would be forced to infer that even the relatively low average take by Alaskan Eskimos up to the 1970's was nonetheless sufficient to hold the population static. There is little reason to suppose that any significant man-caused environmental change had occurred that might significantly affect population growth. There is evidence, however, that mass mortality

¹Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Simulated 1978 population sizes for mortality rate (M) of 0.05 and various 1912 population sizes (average of 500 simulations).

Net recruitment rate ($r-M$)	Lag	1912 population size					
		600	700	800	900	1,000	2,000
0.05	0	4,695	7,175	9,771	12,095	14,688	39,740
	5	1,999	2,954	3,947	4,856	5,845	15,485
	7	1,661	2,432	3,232	3,698	4,765	12,544
0.04	0	1,373	2,699	4,021	5,326	6,656	20,055
	5	870	1,511	2,154	2,788	3,434	9,925
	7	787	1,327	1,871	2,407	2,952	8,433
0.03	0	28	534	1,243	1,953	2,667	9,645
	5	123	543	970	1,396	1,824	6,025
	7	160	538	914	1,291	1,668	5,381
0.02	0	—	—	48	331	709	4,397
	5	—	13	220	484	760	3,454
	7	—	37	266	510	765	3,250
0.01	0	—	—	—	5	2	1,732
	5	—	—	—	5	102	1,765
	7	—	—	0	24	165	1,767

Table 2.—Simulated 1978 population sizes for mortality rate (M) of 0.07 and various 1912 population sizes (average of 500 simulations).

Net recruitment rate ($r-M$)	Lag	1912 population size					
		600	700	800	900	1,000	2,000
0.05	0	4,911	7,394	9,999	12,300	14,904	39,963
	5	1,861	2,697	3,571	4,363	5,232	13,691
	7	1,530	2,196	2,889	3,523	4,213	10,939
0.04	0	1,519	2,842	4,163	5,463	6,796	20,208
	5	878	1,450	2,026	2,591	3,168	8,976
	7	787	1,264	1,743	2,215	2,696	7,533
0.03	0	64	626	1,335	2,047	2,762	9,732
	5	200	591	982	1,371	1,763	5,600
	7	237	579	919	1,260	1,601	4,953
0.02	0	—	—	87	392	772	4,459
	5	—	63	302	549	808	3,332
	7	—	114	346	572	809	3,117
0.01	0	—	—	—	—	7	1,777
	5	—	—	1	45	198	1,804
	7	—	—	8	107	266	1,804

due to ice entrapment has occurred in the past though the frequency and extent of this phenomenon is little known (Sleptsov, 1948, as cited by Tomilin, 1957). The Alaskan Eskimo take averaged less than 20 individuals annually prior to 1970 (Marquette and Bockstoce, 1980). This rate of take, if the 1912 population was in excess of 2,000, would indicate that this population has had a remarkably low potential for increase.

A further factor concerning the issue of continually declining levels is that the decline of commercial exploitation is frequently attributed to difficulty in finding whales. It seems improbable, given their tendency to concentrate, that a bowhead whale population numbering about 2,000 would be difficult to locate—especially by the efficient and far-ranging steam whalers operating after about 1890. However, the evidence on this point is largely anecdotal at present (Allen, 1978). Braham and Krogman² report data from Townsend (1935) that show a sharp decline in catch by 1875, with a very slight increase under steam whaling. Catch per vessel did increase appreciably from

about 1890 to 1905 (Figure 1 of Braham and Krogman, footnote 2), reflecting the increased efficiency of the steam whalers. Commercial exploitation became unprofitable by 1908 (Rice, 1974; Bockstoce, 1977; Allen, 1978) due to a drastic decline in the value of baleen.

We expect that increasing knowledge about the biology of bowhead whales will permit substantial improvements in the present model. When certain essential parameters have been estimated, it should be possible to produce a more realistic model and to improve the procedure used here. Without the lag term, our model (Equation (2)) is simply that of a difference equation for geometric growth (if catches are set to zero). Similarly, the model of Breiwick et al. (In press) reduces to the difference equation analog of the ordinary logistic growth model.

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²Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort seas.

Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

Sampling Strategy for Enumerating the Western Arctic Population of the Bowhead Whale

BRUCE D. KROGMAN

Introduction

The National Marine Mammal Laboratory (NMML), National Marine Fisheries Service, NOAA, is conducting research on the population enumeration of the western Arctic stock of the bowhead whale, *Balaena mysticetus*. From a management viewpoint this research is critical for evaluating the status of this severely depleted stock. Because so little is known about the bowhead, inferences regarding the health of the population arise mostly from changes in total population size. The basis for this inference is the assumption that changes in population size reflect the summation of all life history processes of the bowhead. To state it rather coarsely, for this depleted stock a decline in total abundance may indicate a shift toward extinction; an increase, a shift toward survival.

At present our only scientific means of assessing the number of whales which can be safely removed from the bowhead stock is to estimate total abundance and then rely on theories of population growth to predict acceptable levels of removal. But estimating total abundance is a very costly endeavor for a wide ranging species like the bowhead and, furthermore, there is no guarantee that general theories of population growth will always apply. Regardless of the population level there is the possibility of decline induced, perhaps, from stress relating to activities of offshore oil development, subsistence harvest, or natural fluctuations of the ecosystem. It is with these

problems in mind that this paper presents the NMML research strategy for estimating total abundance of the bowhead whale and discusses methods

which eventually may be used to monitor relative abundance, i.e., annual changes in population size.

Study Area

The study area closely approximates the range of the western Arctic population of bowhead whales (Fig. 1). The range extends from the west-central Bering Sea north of approximately lat. 60°N, throughout the Chukchi and eastern East Siberian Seas, and eastward throughout the U.S. Beaufort Sea to Banks Island and Amundsen Gulf, Northwest Territories, Canada.

Seasonal movements of bowhead

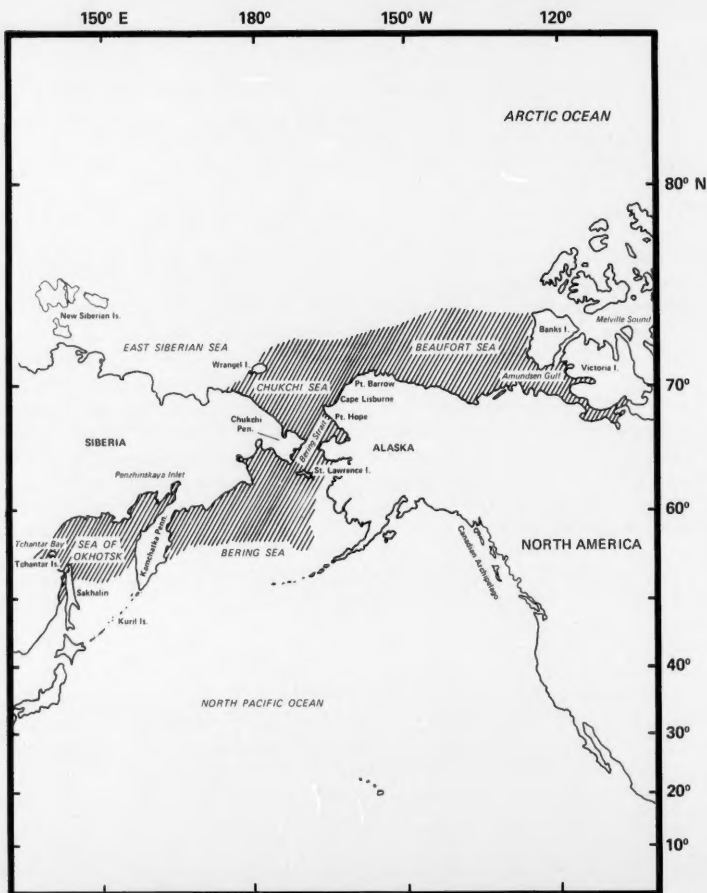


Figure 1.—Bowhead whale study area. Hatched lines indicate distribution of the western Arctic and Okhotsk populations of bowhead whales prior to commercial exploitation (Braham et al., footnote 4).

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whales closely parallel the seasonal distribution of ice. The northward spring migration from the Bering Sea is timed with the breakup of the pack ice (Bailey and Hendee, 1926) which occurs about April. Upon entering the Chukchi Sea the migration cuts north-eastward toward Point Hope and along the northwest coast of Alaska, toward Point Barrow (Braham et al., 1980). The migration occurs closest to shore at Point Barrow, with most of the population passing from late April through May. Although the direction of migration toward Banks Island does not change, east of Point Barrow the coastline slants southeasterly toward Canada. Thus the spring migration route east of Point Barrow becomes progressively more offshore as the whales move easterly through the Beaufort Sea toward Banks Island.

During the spring migration bowheads confine themselves to open water areas in the pack ice. In their southern range the ice is thin and easily disturbed by winds and currents; open water areas are abundant. As bowheads penetrate further north, however, the ice becomes thicker and flaws in the ice commonly appear as long cracks, or leads. Along the northwest coast of Alaska these leads persist between the landfast ice and the pack ice forming a zone which may exceed 50 km in width towards the southern end near Cape Lisburne (Burns et al.¹). This zone narrows dramatically to only a few kilometers at Point Barrow (Braham et al., 1979). East of Point Barrow the zone occurs further offshore (Marko, 1975).

From June to September bowheads frequent areas south and southwest of Banks Island; the autumn migration westward through the Beaufort Sea begins in August and September, with most sightings recorded in October near the 20 m depth contour line from Demarcation Bay to Point Barrow

(Ljungblad et al.²). From Point Barrow the animals move westward toward Wrangel Island (Cook, 1926; Townsend, 1935) then south through the Chukchi Sea into their winter range, the Bering Sea.

Field Methodology

Ice and Land Camps

Each spring from 15 April through 30 May since 1976 we have counted bowhead whales as they migrated past Point Barrow in the nearshore lead. Because of constant daylight during late spring and summer in the Arctic, a 24-hour observation schedule was maintained. One camp was deployed in 1976 and 1977. In 1978 and 1979 two camps with seven persons each were deployed on the landfast ice next to the nearshore lead approximately 5 km north of Point Barrow.

The two camps, called South Camp and North Camp, were located 600-800 m apart depending on the availability of ice platforms or ridges of sufficient height to provide visual observation across the lead.

Bowheads moved northeastward in the nearshore lead from South Camp toward North Camp. South Camp observers maintained the primary count while North Camp observers estimated how many whales were missed at South Camp.

Documentation of the ice camp counting methodology is reported in Braham et al. (1979), Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage (1980), and Krogman et al.³.

A land camp was located at Cape Lisburne in 1978 to study the onset and termination of spring migration along

the northwestern coast of Alaska. Land camp methodology was similar to that used in the ice camps except that only one camp was used (Rugh and Cubbage, 1980).

Aerial Survey

Aerial survey procedures were designed to maximize our ability to delineate nearshore and offshore distribution of whales in seas covered with pack ice. The aircraft was flown over leads at elevations ranging from 70 to 300 m depending upon cloud cover. Documentation of aerial survey methodology used for this research is reported in Braham et al.⁴ and Krogman et al.⁵.

Total Abundance

Results from aerial surveys flown to delineate the spring distribution of bowhead whales in the Bering, Chukchi, and Beaufort Seas, and results from feasibility studies conducted at St. Lawrence Island, Cape Prince of Wales, Point Hope, Cape Lisburne, and Point Barrow, indicate that the most reliable estimate of total abundance will result from counts made from the ice as migrating bowhead whales pass Point Barrow, Alaska, during their spring migration. Census methods which relied on aerial survey methodology were quickly disqualified because of the confounding effects of sea ice on sampling design. The other above-mentioned sites were considered for staging land/ice based counts, but each eventually proved inferior based on the criteria of proximity of location to migratory routes, ice, and prevailing weather conditions which influence visibility.

Counts made at Point Barrow do not constitute a complete census, however. In fact, before one can use the Barrow

¹Burns, J. J., L. H. Shapiro, and F. H. Fay. 1977. The relationships of marine mammal distributions, densities, and activities to sea ice conditions. In *Environmental assessment of the Alaska continental shelf*, annual reports of principal investigators for the year ending March 1977, Vol. 1, Receptors-mammals, p. 503-554. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

²Ljungblad, D. K., M. F. Platter-Rieger, and F. S. Shipp. Jr. 1980. Aerial surveys of bowhead whales, North Slope, Alaska. Naval Ocean Systems Center Tech. Doc. 314, Final rep., Fall 1979, BLM Project No. 00L80AA851-1A0-1-ELEMENT OGB, 182 p. Bureau of Land Management, Code 733, 18 and C Streets N.W., Rm. 2657, Washington, DC 20240.

³B. D. Krogman, G. W. Priebe, and R. M. Sonntag. 1980. Arctic Whale Task ice camp survey data management format, document 1980 version. Unpubl. rep., 30 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

⁴Braham, H., B. Krogman, and G. Carroll. 1979. Population biology of the bowhead whale (*Balaena mysticetus*) II: Migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution of white whales (*Delphinapterus leucas*). Unpubl. final rep., OCSEAP contract R7120807, 118 p., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

⁵Krogman, B. D., R. M. Sonntag, and H. W. Braham. 1979. Arctic Whale Task aerial survey format, 1979 version. Unpubl. rep., 28 p., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

counts as the basis for estimating total abundance, it is necessary to consider all segments (components) of the bowhead population not accounted for by the Barrow counts.

To proceed along this line of reasoning, a total estimate (T) for the bowhead population can be expressed mathematically as:

$$T = \sum_{i=1}^n C_i \quad (1)$$

where T = total population size,

C_i = i th component of the population, and

$n = 5$.

Letting C_1 = number of whales passing the ice camp during a specific sampling period in the spring (15 April-30 May),

then C_2 = number of whales passing by Barrow before the spring sampling period,

C_3 = number of whales passing by Barrow after the spring sampling period,

C_4 = number of whales which never pass the ice camp, perhaps remaining in the Chukchi and Bering Seas through summer, and

C_5 = number of whales passing by Barrow far offshore, beyond the range of sight of the observers at the ice camp.

The advantage of this technique is that each component can be studied separately and later combined to make a total abundance estimate. Research strategies for estimating each component will now be presented.

C_1 is typically greater than actual counts because there are intervals during the 15 April through 30 May period during which observers are unable to watch for whales. Unstable ice conditions and/or periods of poor visibility because of fog or ice-choked leads sometimes prevent observers from counting. It is thus necessary to interpolate for periods of missed watch so that C_1 will equal the total number of bowheads passing the counting stations during the field season.

To proceed, let C_1 be estimated by \hat{C}_1 , defined as:

$$\hat{C}_1 = \sum_{i \text{ odd}}^n w_i + \sum_{i \text{ even}}^n w_i \quad (2)$$

where $\sum_{i \text{ odd}}^n w_i$ = summation of the number of bowheads counted during each period of watch, and

$\sum_{i \text{ even}}^n w_i$ = summation of the number of bowheads estimated as moving by the camp during periods of no watch.

The length of each period w_i will vary with environmental conditions. The first watch period of the season w_1 lasts until observers must abandon watch. At the moment w_1 terminates, w_2 begins and continues until observers return to watch, demarcating the initiation of w_3 , and so on.

Obviously the value of each w_i odd equals the number of whales counted during each period of watch. It is now left to estimate w_i even. After considerable investigation of alternative methods, such as polynomial curve fitting, it was concluded that for any missed period x , w_i even can best be approximated by interpolation using the average rate(s) of whale movement based on counts made during the two adjacent periods, each also equal in length to period x . Thus, if 2 hours are missed, an estimate of that missed period is calculated based upon the preceding 2 hours and following 2 hours of data. If 3 days are missed, then 3 days preceding and 3 days following are used. Also, as is likely to occur in the latter example, if some portion of an adjacent period is also missed, the rate is computed on whatever data are available in that adjacent period.

The computation of \hat{C}_1 yields a value similar to that reported as the "ice camp index" in Braham and Krogman⁶ and

Braham et al. (1979), particularly when only a small percentage of the total watch period is missed. The ice camp index was computed as the summation of the products of the average rate of whales per hour of watch during each day multiplied by 24 hours. In 1978, it was computed as 2,264 with a total range of uncertainty equal to 1,082 (Braham et al., 1979). Regretfully, the term "index" has been a source of confusion for some, and thus the term C_1 is introduced here as the "Barrow estimate."

C_2 and C_3 were evaluated by a field study conducted at Cape Lisburne in the early spring of 1978 (Rugh and Cubbage, 1980). The main objective of that study was to determine the onset and termination of the spring migration along the northwestern coast of Alaska. Results were combined with aerial survey results and ice camp counts to estimate the magnitude of C_2 and C_3 .

The value of C_2 was negligible according to results from Cape Lisburne. Bowheads were seen migrating past Cape Lisburne before Point Barrow. In 1978, regular watches at Cape Lisburne commenced 10 April and the first confirmed sighting of bowheads occurred 8 days later; bowheads were seen daily thereafter. At Point Barrow, regular watches commenced 15 April, and the first bowhead was observed 5 days later. Again, they were seen daily thereafter. These similarities in temporal distribution indicate that few, if any, bowheads migrated past Point Barrow prior to the commencement of the Point Barrow ice camp census.

C_3 is estimated to be less than 4 percent of C_1 . This estimate for the number of bowheads moving by Point Barrow after the spring sampling period was derived from ice camp data and was verified by results from aerial surveys, as explained below.

A comparison of trends in daily movements of bowhead whales migrating by Point Barrow for the years 1976-78 (Fig. 2) showed a decline in movement during the last third of the 15 April through 30 May period. An average rate per day beyond 30 May was computed as 3.08 (0.94 SD). The ending dates of our observations for each year were: 2 June 1976, 3 June 1977, 5 June 1978, and 30 May 1979. Using

⁶Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

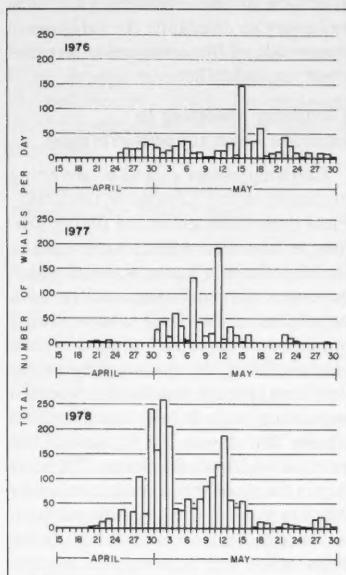


Figure 2.—Comparison among years (1976-78) of estimated total number of bowhead whales migrating northward past Point Barrow, Alaska, 15 April-30 May. For purposes of comparison, totals are based on hourly rates per day times 24 hours. Estimated yearly totals are 796, 715, and 2,264 for 1976, 1977, and 1978, respectively. Differences in total estimates are ascribable to observer effort and weather. The 1978 estimate is considered the best available to date (Braham et al., 1979).

only this average as a basis for extrapolating through the month of June, it can be estimated that approximately 92 whales pass Point Barrow after the ice camp counting station closes.

Aerial survey results suggest, however, that daily rates decline through the month of June. Figures 3 and 4 illustrate the difference in the number of bowhead whales observed during the first week versus the third week of June 1976. Thus, the estimated 92 whales can be considered a maximum value. The value 92 is 4 percent of 2,264, which is the current estimate of the number of bowheads which pass Point Barrow during the 15 April through 30 May period (Braham et al., 1979).

C_4 is apparently insignificant. Results from vessel and aerial survey re-

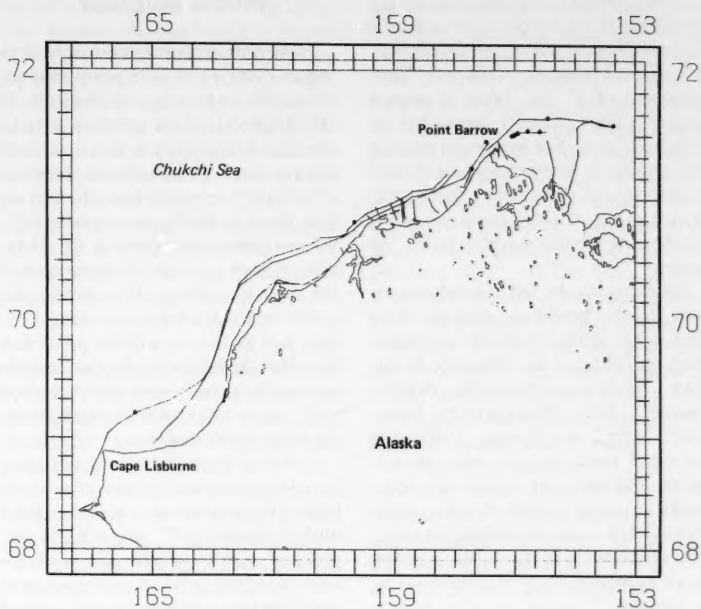


Figure 3.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 1, 4, and 5 June 1976. Dots represent presence of bowhead whales: 20 whales were counted with a mean group size of 1.8 (SD=1.1).

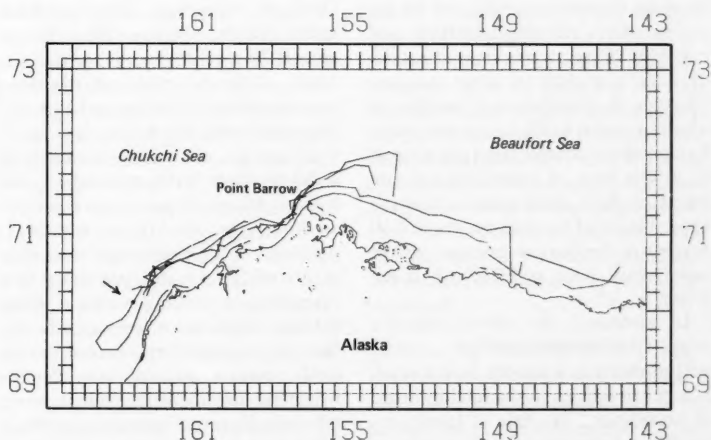


Figure 4.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas 18-20 June 1976. The dot (indicated by an arrow) represents one bowhead whale.

search conducted since 1976 indicate that few if any bowhead whales remain in the Bering and Chukchi Seas south of

the pack ice after the closure of the ice camps (Braham et al., footnote 4; Dahlheim et al., 1980).

C_5 is difficult to measure because the perimeter of the sample space, i.e., the farthest distance that observers can reliably count whales, is not discrete. Measurement of C_5 has been attempted primarily through aerial survey, but results have been slow in coming because the number of bowheads is small, and technological limitations have prevented an accurate determination of the position of whales relative to the ice camps.

Based on results from aerial survey, few, if any, bowheads migrate more than 8 km seaward of the ice camp; most are within 3 km (Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980). On the other hand, results from the ice camps indicate that almost all bowheads migrate within 5 km—most within 1 km—of the landfast ice edge. This discrepancy is ascribable to differences in methodology that have yet to be resolved.

Further complicating the determination of the magnitude of C_5 is the probability that the number of whales passing beyond the range of sight of observers is not constant. Yearly fluctuations in ice configurations may contribute to shifts in whale distribution relative to the ice camps. And, certainly, location and condition of ice at the camps affect the observer's ability to count whales. Changes in distributional patterns of whales relative to the ice camps therefore prevent a reliable determination of C_5 at this time. A subjective estimate based on field experience is that the upper bound of C_5 does not exceed 30 percent of the Barrow estimate and in some years, such as 1978, it is much lower.

In summary, the above analyses suggest that components C_2 , C_3 , and C_4 will probably account for only a small number of whales in the total estimate of abundance. Too little is known regarding the magnitude of C_5 to predict its effect on future estimates. Furthermore, this analysis supports the conclusions made by Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage (1980) that the "ice camp index" or "Barrow estimate" under certain conditions can serve as an approximation of total abundance.

Relative Abundance

Until now, out of interest in presenting an overview, I have postponed any discussion of accuracy or precision. In all likelihood, if the estimate of total abundance is accurate, it will also be precise, but not vice versa. A statement of accuracy describes how close to the true value a particular estimate falls, whereas precision refers to the closeness of each repeated measurement of the same quantity. In this section, the research strategy for determining accuracy and precision will be presented. Note that the following discussion deals almost exclusively with the evaluation of C_1 , as its magnitude so overshadows the other components.

A typical approach to studying accuracy is to uncover sources of error or bias. The sources of error associated with estimating C_1 are closely associated with how well observers are able to count whales. An obvious error would be for an observer to miss seeing a whale altogether (e_1). This error was studied in 1978 and 1979 using two ice camps (see Field Methodology section) and is estimated at approximately 20 percent, i.e., 20 percent of all whales which swim by one camp are never seen (Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980). Other errors occur, but these must be defined as they relate to the way observers score whales.

Observers are asked to score all sightings made during a period $w_{i, odd}$ as: New sightings, duplicate or repetitive sightings, or conditional sightings, which occur when observers are unsure as to which of the previous two categories in which a whale sighting belongs. Here, error terms can be defined as: e_2 , when an observer incorrectly scores a whale as new after the whale has already been counted; or e_3 , when an observer incorrectly scores a whale as a duplicate before it has been counted as a new whale. No error per se can be made regarding conditional whales.

To determine the accuracy of the estimate of C_1 it is necessary to determine the magnitude of e_2 and e_3 and to determine, if possible, the proportion of conditional whales which were new rather than duplicates. To determine the

precision of the estimate of C_1 , it is necessary to determine the variation in magnitude of these sources of error—observer variability.

Computer Modeling to Improve Accuracy and Precision

Counting errors e_2 and e_3 are being evaluated using computer modeling. Field data collected on the diving profiles of bowhead whales were used as the basis for developing a model which generates the surfacing pattern of a population of bowhead whales during migration. The model creates a data base similar to the one based upon raw field data, except that for the modeled population, it is known exactly which whales that "swim by the camp" are new and which are duplicates. The next step in the modeling procedure involves the development of a counting program to independently evaluate the model population for new and duplicate whales. As the counting program processes each "sighting" it evaluates it against all previous sightings and, based upon probabilities, the program decides whether or not the sighting is new or duplicate.

On the average, the counting program overestimates the number of new whales by 8 percent, and underestimates the number of duplicate whales by 2 percent. But these results must be further verified through field experiments. The counting program will be implemented in the field through use of a microcomputer. As observers at the ice camps record observations, they will also relay their data by radio to a nearby laboratory for evaluation by the counting program. Feedback based upon computer evaluation will then be provided to the observer. Through this two-way communication much can be learned about the nature of errors made by observers and by the counting program.

The results of this study will be applicable to evaluation of accuracy and precision of the estimate of C_1 . Assuming that the counting program is verified, it will be applied to previous years' field data for evaluation of counting errors. Upward or downward adjustments can be made, resulting in a more accurate estimate of C_1 . Since adjustments in counts will also have the effect of negating much of the observer

variability apparent from year to year (see Table 1, Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980), the precision of the estimate of C_1 will also be improved.

Measurement of Accuracy and Precision for Missed Data

Unfortunately, there are more factors than just observer variability which influence the accuracy and precision of the estimate of C_1 by Equation (2). As environmental conditions worsen, and observational effort becomes more discontinuous, the accuracy and precision of the estimate of C_1 become a concern. Simply stated, an estimate of C_1 based upon 95 percent watch effort would be considered more reliable than an estimate based upon only 35 percent. For the 95 percent case, interpolation to determine the number of whales which passed the ice camp during periods of missed watch would be required 5 percent of the time; for the latter case, 65 percent of the time. Thus, as percent watch effort decreases, the estimate of C_1 becomes less a measurement and more an inference.

The accuracy of Equation (2) and the rate at which its precision decreases are being studied with the aid of a computer model. The basis of this model is a data base which contains whale counts made during a continuous period of watch which lasted 18 days from 2 to 20 May 1978. The total number of whales counted during this period equaled 1,133 and, for the purposes of this experiment, is considered equal to C_1 , the true number of bowheads which passed the counting station.

The model simulates the effects of reduced watch effort by introducing periods of missed watch which vary in length and frequency. Theoretically, watch effort can be varied from 0 to 100 percent, but for practical reasons, experiments have been run from 6 to 98 percent by increments of 2 percent. A determination of accuracy and precision is made for each increment.

As an example of how accuracy and precision are determined for a given percentage of watch effort, consider a season where 80 percent of the time was spent watching. The model would initially remove 20 percent of the data, and

calculate an estimate of C_1 . The difference between the estimate and the true C_1 is called a residual. Following this, the model would reselect 20 percent of the data for removal, and recompute C_1 , again computing a residual. After performing this test many times, an average and standard deviation are computed for the residuals.

It is the average of the residuals which is used to evaluate accuracy. Theoretically, if the experiment is repeated often enough and if Equation (2), which is used to estimate C_1 , is unbiased, then the average residual should equal zero; that is, there should be no difference between estimated and true values of C_1 . A significant upward departure from zero indicates that Equation (2) is upward biased, i.e., tends to overestimate the number of whales which swim by during periods of missed watch. A significant downward departure similarly indicates that Equation (2) is downward biased. Preliminary results suggest that Equation (2) is unbiased, or accurate.

The standard deviation of the residuals forms the basis for determining precision. When Equation (2) repeatedly estimates C_1 very closely, the standard deviation of the residuals will be small, indicating good precision. When repeated estimates of C_1 vary widely, the standard deviation of the residuals will be large, indicating a lack of precision. Through the use of the computer model, the rate of growth of the standard deviation is being traced as a function of watch effort.

In summary, this research should eventually provide the criteria which will allow annual changes in estimates of C_1 to be evaluated statistically, thus improving the chances of detecting significant changes in population size if and when they occur. Furthermore, the evaluation will take into account variations in percent total watch effort, thereby increasing the usefulness of marginal counting years for monitoring population stability.

Discussion and Conclusion

This paper was written primarily to explain the National Marine Mammal Laboratory's research strategy for population enumeration of bowhead whales. Other avenues of research that have been seriously investigated have

not been addressed in this report. For example, censusing techniques using active and passive acoustic devices have received considerable attention (Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980; Braham, Krogman, Nerini, Rugh, Marquette, and Johnson, 1980). Aircraft have been used as platforms for validating ice camp counts (Braham et al., 1979). Even remote sensing methods which utilize satellites have been explored. These alternative censusing methods are being investigated because it is through independent verification of research results that meaningful statements regarding population abundance can be made.

It should be remembered, too, that no matter how difficult it may be to estimate total population size, it is entirely feasible that we can monitor the status of this population by detecting changes in its size through time. One simple approach might be to eliminate the problem of observer judgments and whale counting by having observers record only the number of sightings they make without attempting to translate the number of sightings into number of whales. For example, assuming environmental factors are standardized, if the number of sightings increases 5-fold over a period of years, an inference could be made that the total population size is also increasing. It would be premature to adopt this methodology, however, since it has not been shown that observers do not count accurately. It may be that inquiries will show not only that observers are highly reliable, but that both total abundance and relative abundance can be reliably estimated.

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Spring Migration of the Western Arctic Population of Bowhead Whales

HOWARD W. BRAHAM, MARK A. FRAKER, and BRUCE D. KROGMAN

Introduction

Each spring the western Arctic population of bowhead whales, *Balaena mysticetus*, migrates from the Bering Sea, through the Chukchi Sea, and into the Beaufort Sea. For centuries, coastal Eskimos of western Alaska and eastern Siberia have taken bowheads during spring as the whales moved past their villages soon after openings formed in the pack ice. Traditionally, Eskimos sailed or paddled their boats out into cracks and open water areas in the ice, called leads and polynyas, respectively, from April to June to hunt the whales. The breakup of the pack ice and migration pattern of the whales are so regular that the whales are reliably accessible to whalers each spring, but only for a few weeks. At St. Lawrence Island, Alaska,

for example, present-day whaling occurs from approximately the first week in April to about the first week in May; at Barrow, Alaska, the peak of both migration and whaling activity occurs from the last week in April to the last week in May (Braham and Krogman¹; Marquette², 1979; Braham et al., 1979; Braham et al.³).

¹Braham, H., and B. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

²Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

³Braham, H., B. Krogman, and G. Carroll. 1979. Population biology of the bowhead whale (*Balaena mysticetus*) II: Migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution of white whales (*Delphinapterus leucas*). Unpubl. final rep., OCSEAP Contract No. R7120807, 118 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

Townsend (1935) plotted the locations of bowheads killed by Yankee whalers operating in the Bering Sea and Arctic Ocean from 1848 to 1919. His map suggests that bowheads may have formerly occurred in the Bering and Chukchi Seas, as well as in the Beaufort Sea, during the summer months, well beyond the present-day whaling season. Data collected since 1974, however, indicate that bowheads do occur in the eastern Beaufort Sea during the summer (Fraker and Bockstoce, 1980), but that probably only a few occur in the Bering and southern Chukchi Seas during summer (Braham et al., footnote 3; Braham, Krogman, Nerini, Rugh, Marquette, and Johnson, 1980; Dahlheim et al., 1980).

Although the general timing and pattern of movements of bowheads during the spring migration are known (Bailey and Hendee, 1926; Tomilin, 1957; Foote⁴; Durham⁵; McVay, 1973; Braham and Krogman; footnote 1), the precise pathway that they take has not been fully described—especially in the largely frozen Beaufort Sea. In this paper we discuss the spring migration route, March through June, and describe ice conditions encountered by the whales. In addition to gaining an understanding of an important part of

⁴Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpubl. manuscript, 73 p. McGill Univ., Montreal, Quebec, Can.

⁵Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus*) in the western arctic. Unpubl. manuscript, 93 p. Dep. Biol., Univ. South Calif., Los Angeles, CA 90007.

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the species' annual cycle of movements, the primary objective of our study of migration and distribution is to determine what portion of the bowhead population migrates past the National Marine Fisheries Service whale-counting ice camps, described by Braham et al. (1979) and Krogman (1980), to ensure the best possible estimate of the population size.

Study Area and Ice Conditions

The study area included the northern Bering Sea, the Chukchi Sea east of long. 171°W, and the Beaufort Sea and Amundsen Gulf west of approximately long. 120°W (Fig. 1).

Ice is a dominant feature of the study area and a knowledge of its characteristics is critical to understanding bowhead migration. In March or April, the pack ice reaches its maximum extent in the Bering Sea (Shapiro and Burns, 1975). Ice breakup begins as temperatures rise and wind direction shifts from northeast to south or southwest, pushing the ice northward. In the northwestern Bering Sea, between the Chukchi Peninsula and St. Lawrence Island, strong currents further help to break up the ice and form an open-water corridor. North of the Bering Strait, a shear or flow zone forms parallel to the Alaskan coast causing numerous small leads to develop along and near this zone. An intermittent lead system forms from the Bering Strait through outer Kotzebue Sound to Point Hope and on to Point Barrow (Fig. 2). This lead system usually consists of a single, major nearshore lead that lies between landfast ice and the pack ice.

In the Beaufort Sea, two closely related phases of spring ice movement (Marko, 1975) are relevant to whale migration. First, there is a southwestward movement of ice in the northern Beaufort Sea that results in a major shear zone projecting northeastward into the eastern Beaufort Sea, toward Banks Island (Fig. 3). North of this east-west trending shear zone, an extensive system of interconnecting north-south rectilinear leads develops. The shear zone and perhaps the extensive lead system to the north serve as avenues for bowhead and white whales, *Delphinapterus leucas*, migrating eastward through the Beaufort Sea.

Second, a general westward drift of ice in the eastern Beaufort Sea results in extensive lead and polynya development in the eastern portion of the study area. Easterly winds in the eastern Beaufort Sea during spring, in concert with the clockwise rotation of the Beaufort gyre, cause a major north-south lead west of Banks Island and another (often connected) lead north of the landfast ice of the Tuktoyaktuk Peninsula (Fig. 3). During spring, the ice in Amundsen Gulf begins to break up to form a major polynya, which expands and becomes continuous with the leads off Banks Island and the Tuktoyaktuk Peninsula.

Sources of Data

The major sources of data for this paper were aerial surveys and compilations of sightings by NMFS scientists working in the Bering, Chukchi, and western Beaufort Seas 1976-79 (Braham and Krogman, footnote 1; Braham et al., 1979, footnote 3; Brueggeman⁶) and by Fraker in the eastern Beaufort Sea (Fraker et al., 1978; Fraker, 1979). Additional data on location and timing of bowhead movements were also obtained from village residents along Alaska's northwest coast; observers at land and ice camps in northwest Alaska (Braham and Krogman, footnote 1; Braham et al., 1979); researchers on the NOAA ship *Surveyor* operating in the Bering Sea; Soviet investigators⁷; Canadian Wildlife Service scientists and other persons in Canada during 1971-77 (Fraker, 1979); and State of Alaska, Federal, and other scientists who have worked in Alaska over the past 20 years.

Over 150 aerial surveys totaling about 170,000 km in length were carried out in the study area 1974-79. Most surveys were conducted in April and May; others were flown in March and June. Fixed-wing aircraft were used,

most often a DeHavilland Twin-Otter⁸ and a Grumman Goose (N780) equipped with Global Navigation 500 navigational equipment. Flights were either systematic or opportunistic depending on the extent of ice cover, weather, and survey location. For detailed accounts of equipment, survey designs, and methods, see Braham and Krogman (footnote 1); Braham et al. (footnote 3, 1979); Braham, Krogman, Nerini, Rugh, Marquette, and Johnson (1980); Fraker et al. (1978); and Fraker (1979).

Spring Migration

Migration Routes and Timing

During average ice years, bowhead whales spend the winter (January to March) in the pack ice from St. Lawrence Island south to St. Matthew Island (Braham et al., footnote 3; Brueggeman, footnote 6). During years when the pack ice is extensive, such as in 1976 and 1977, the whales can occur as far south as the Pribilof Islands. Only two bowheads have been sighted in open water south of the ice front in the spring (Fig. 4).

Aerial survey data collected since 1976 reveal that the bowhead migration begins in the western part of the northern Bering Sea. From the area west of St. Matthew Island and southwest of St. Lawrence Island, bowhead whales migrate past the west end of St. Lawrence Island taking at least two routes (Fig. 5). First, some whales approach St. Lawrence Island near Southeast Cape where a polynya frequently forms; these animals then head west along the south side of the island and then north along the west side, passing the village of Gambell⁹. Some of these animals may migrate around the east end of St. Lawrence Island; however, this area does not appear to be an important migration route (Braham et al., footnote 3). Second, a portion of the population also approaches St. Lawrence Island near Southwest Cape and then migrates northwestward offshore

⁶Brueggeman, J. 1979. Early spring distribution of bowhead whales in the Bering Sea. Unpubl. manuscript, 22 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

⁷G. Fedoseev, Pacific Scientific Research Institute of Fisheries Oceanography (TINRO), Magaden, Nagaevskaya 51, 685013, U.S.S.R., and A. Berzin, TINRO, Vladivostok, U.S.S.R. Pers. commun.

⁸Reference to trade names or commercial firms does not necessarily imply endorsement by the National Marine Fisheries Service, NOAA, or LGL, Ltd.

⁹C. Oozeva, R. Silook, and V. Silooko, Gambell, AK 99742. Pers. commun.

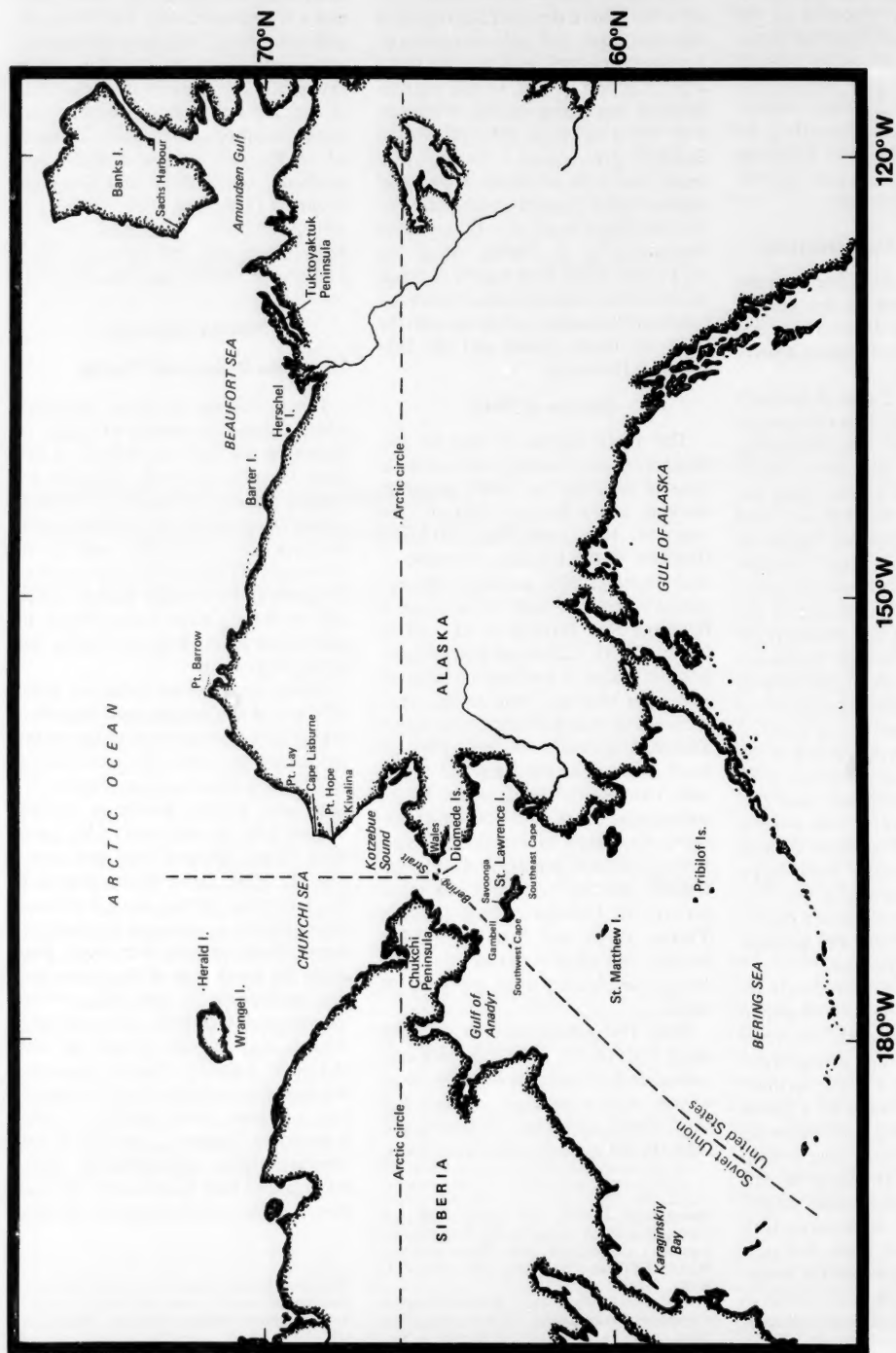


Figure 1. — Western Arctic bowhead whale population study area.

to near the coast of Siberia well away from the village of Gambell (Fig. 5). Therefore, some animals migrate close to the west end of St. Lawrence Island and others far offshore. Although we have not been able to confirm this specific migration near St. Lawrence Island, Eskimo whalers there are convinced of it.

Survey results from 1976 to 1978 suggested that bowheads migrate north through the northwestern Bering Sea and the western part of the Bering Strait. It is the available open water that governs what part of the Strait they use; in some years the east side is undoubtedly used. Apparently, few of the bowheads moving toward the Bering Strait travel near the coast of Alaska. Eskimo whalers at Wales, Alaska, occasionally take a whale near their village during spring (Marquette, footnote 2) when ice conditions permit the whales to use the eastern part of the Strait.

On 24-26 April and 22 May 1978, we conducted six aerial surveys of the Bering Strait. As in April 1976 and 1977, ice cover was extensive across the Bering Strait but somewhat more broken on the Soviet side than the U.S. side. Sixty-seven bowheads, including three calves, were observed just north of the Diomed Islands; they had apparently moved north through the western two-thirds of the Strait (Fig. 4). Their mean true heading was 35.5°N ($n=32$), which is in direct line to Point Hope.

Upon entering the Chukchi Sea, the whales move northeastward across outer Kotzebue Sound in recurring leads seaward of the landfast ice (Fig. 2; small leads not apparent in this photograph). Bowheads appear to migrate in these leads in outer Kotzebue Sound. Some whales move into a polynya that typically forms between Kivalina and Point Hope, but the extent of use of this polynya is unknown. Figure 2 shows that open water was prevalent inside Kotzebue Sound on 26 April 1978. Often this is not the case; characteristically a prominent lead develops along the edge of landfast ice extending in a direct line from the Bering Strait to Point Hope (Fig. 3).

Some Eskimo whalers suggest that a segment of the bowhead population moves northwestward from the Bering



Figure 2.—NOAA satellite image, 26 April 1978, of the spring lead system which forms from the Bering Strait to Point Barrow. Light areas are ice, dark areas are water or thin ice (newly refrozen lead).

Strait into the western Chukchi Sea in the spring. We believe that this is unlikely as there is usually complete ice cover north of the Chukchi Peninsula and west of long. $169^\circ30'\text{W}$ with few leads present (Shapiro and Burns, 1975; Fedoseev, footnote 7). A few flights were made over Soviet waters in March, April, and June 1976 and May and June 1978; the area was almost completely ice covered and no whales were seen. Because the whales we observed north of the Bering Strait in April 1978 were heading east of north, and because ice cover was so complete to the west, it does not seem likely that bowheads were present west of long.

$169^\circ30'\text{W}$. Furthermore, although Siberian Eskimos living along the east side of the Chukchi Peninsula hunted bowheads in the spring, those along the north coast never did (Tomilin, 1957). North coast Siberian Eskimos hunted bowheads only in the autumn (Marquette and Bockstoe, 1980).

Proceeding on a heading of $35^\circ\text{--}45^\circ$ true, bowheads follow open leads northward past Cape Thompson and Point Hope, and then northeastward to Cape Lisburne and Point Barrow. The migration past Cape Lisburne seems to follow two or more corridors occurring 2-10 km offshore, but a few sightings have been made up to 15 km offshore

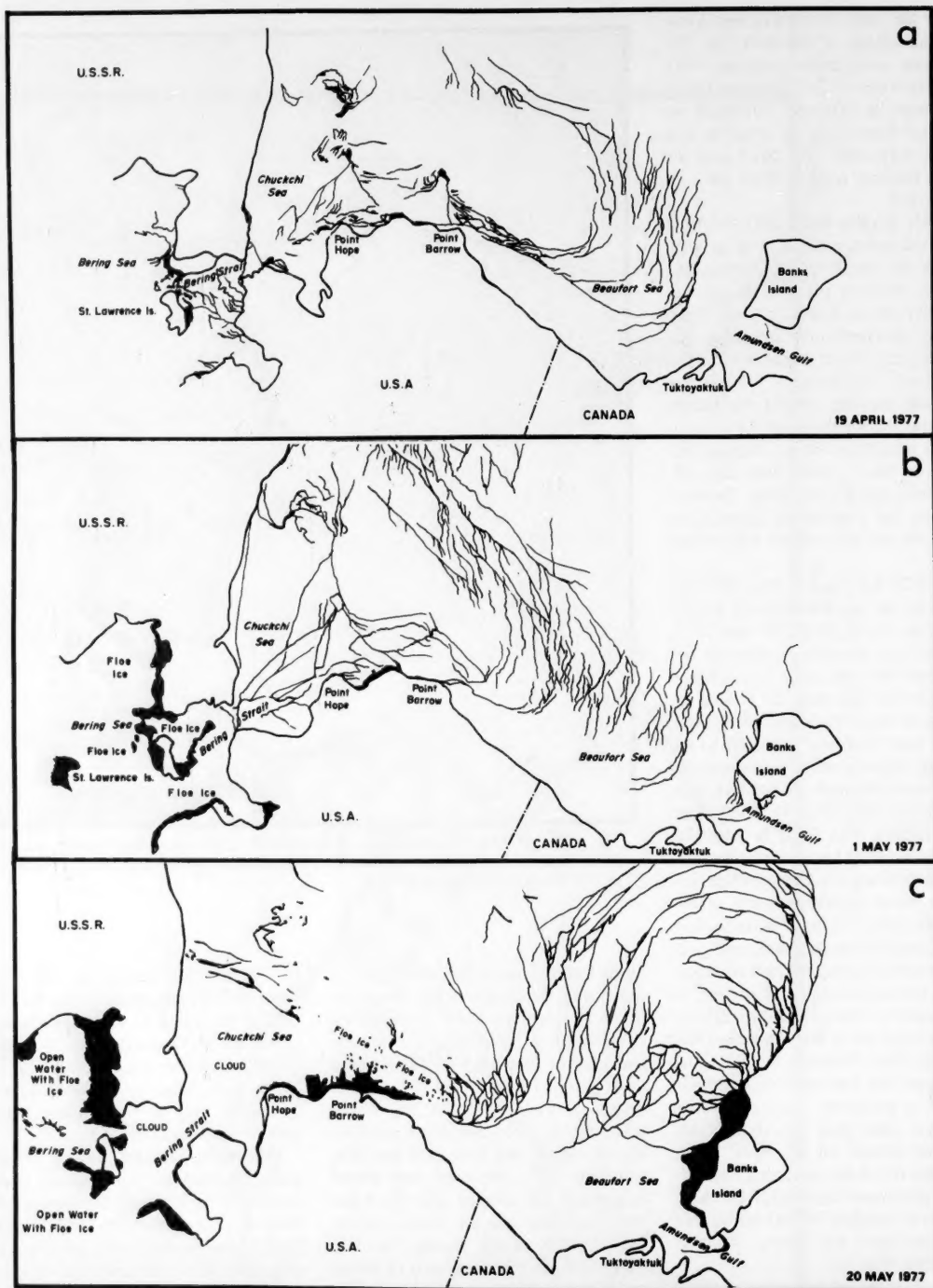


Figure 3.—Pattern of lead development in the Bering, Chuckchi, and Beaufort Seas, April and May 1977. Drawn from NOAA satellite imagery; differences in proportions between drawings are due to differences in satellite position.

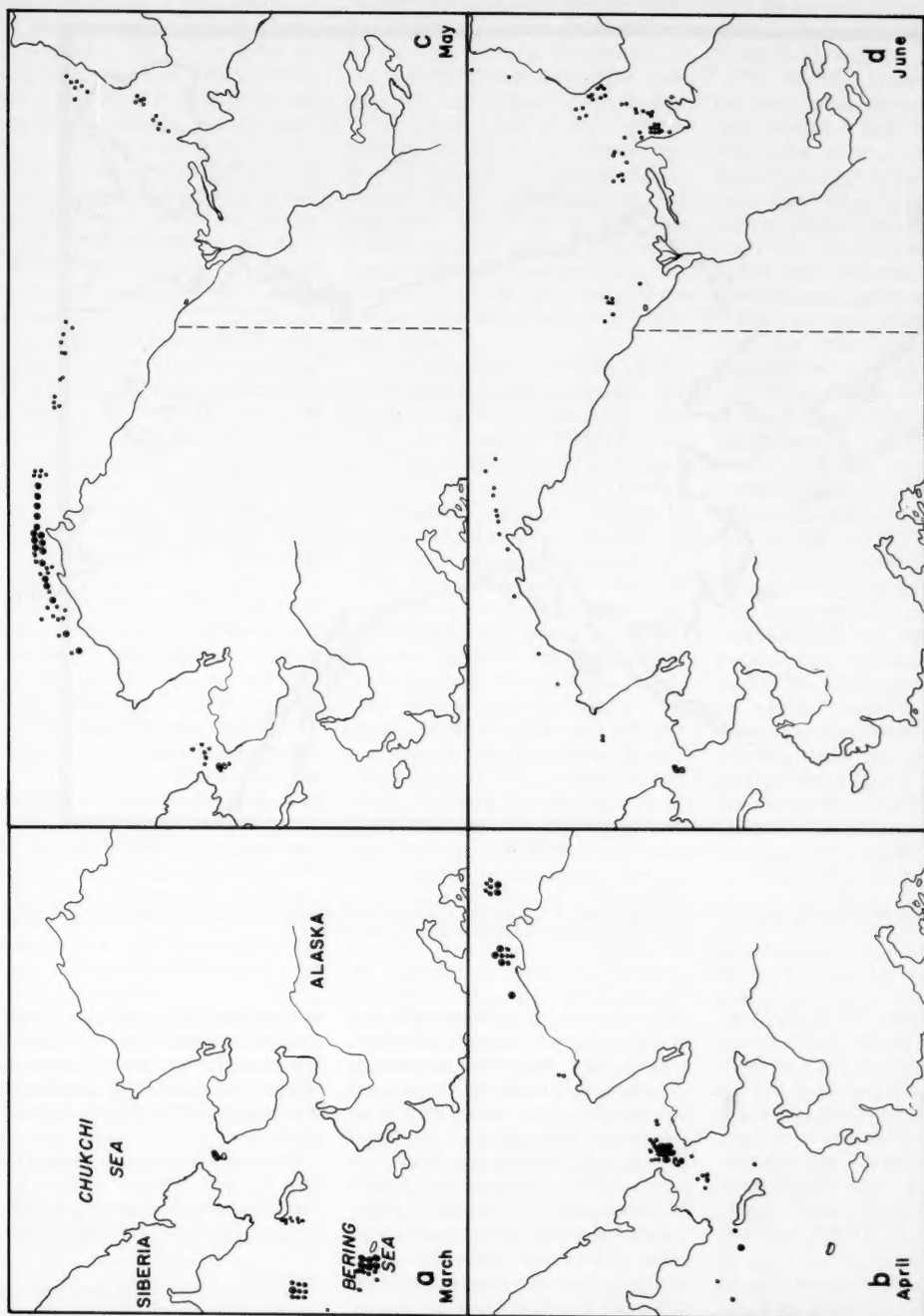


Figure 4.—The location of observations of bowhead whales, 1974-79. Small dot = 1 whale; large dot = 10 whales.

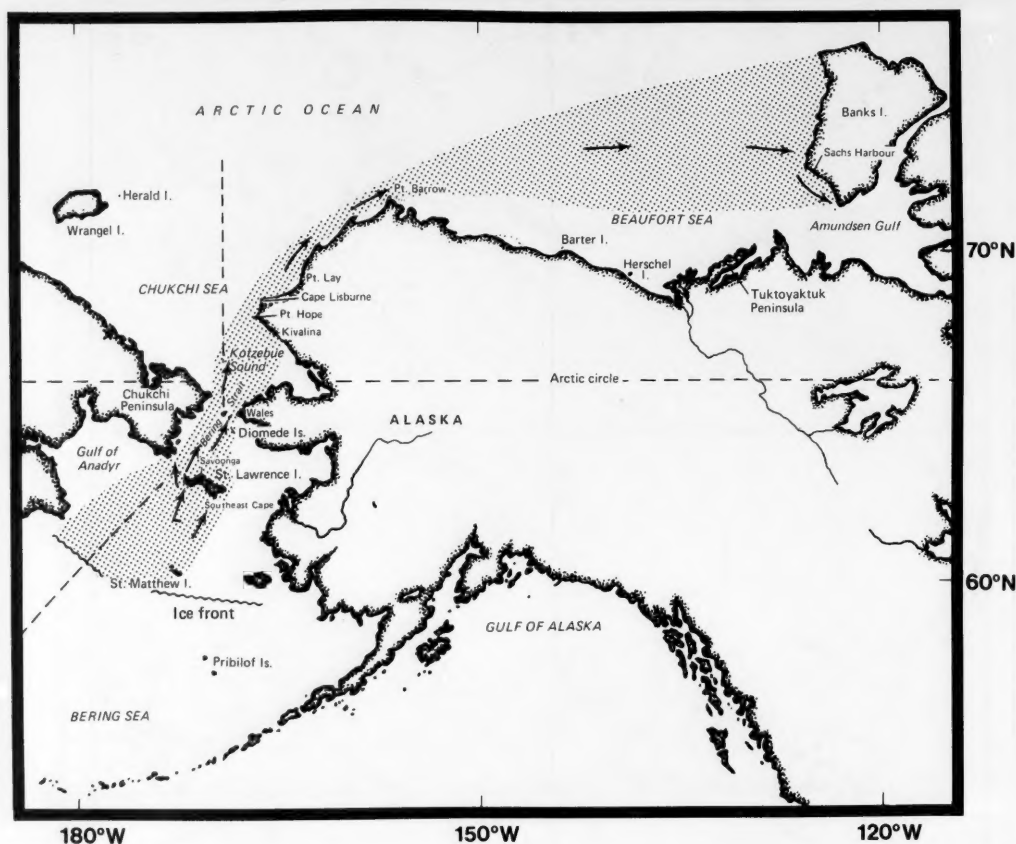


Figure 5.—Generalized spring migration route of the western Arctic population of bowhead whales. Data compiled from aerial surveys and interviews with Alaskan Eskimos, 1976-79.

(Rugh and Cubbage, 1980). Northeast of Cape Lisburne, bowheads apparently migrate only in the nearshore lead. During 4 years of aerial surveys we have observed bowheads only in the lead adjacent to the landfast ice between Point Lay (northeast of Cape Lisburne) and Point Barrow, even though aerial survey time was divided about equally between offshore (to 100 km) and near-shore areas.

The earliest known recording of bowhead whales arriving at Point Hope was 19 March (Foote, footnote 4) and at Barrow on 29 March (Brower, 1942). These dates are considerably

earlier than normal, perhaps a reflection of light ice years. Usually bowheads begin going by Point Hope and Barrow in mid-April. The earliest date in April bowheads have been seen at Point Hope was 11 April (Johnson et al., 1966) and 16 April at Barrow (Brower, 1942). Recent studies conducted by NMFS biologists since 1974, which generally started before mid-April, have not resulted in observations of bowheads before those dates listed above. The latest confirmed bowhead sightings beyond the whaling season (April-June) between Point Hope and Barrow were on 19 June (Braham et al., footnote 3). The

main portion of the migration along the northwest coast of Alaska past Barrow begins in the last week in April and continues through May (Maher and Wilimovsky, 1963; Fiscus and Marquette¹⁰).

Marquette (footnote 2), Foote (footnote 4), and Eskimo whalers have stated that the bowhead migration along the northwest coast of Alaska occurs in

¹⁰Fiscus, C. H., and W. M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Processed rep., 23 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

"waves" or "pulses." At least two pulses were evident at Point Barrow in each year of our study 1976-78 (Figure 2 in Krogman, 1980). One pulse occurred in late April-early May, and the other in mid-May. A third pulse may occur between late May and mid-June, but our data are incomplete for this period. The significance of this bimodal, or possibly trimodal, distribution is unknown, but it may be associated with age and/or sexual segregation within the population. Eskimo whalers state that cows with calves, and large males, do not arrive at Barrow until late May and June. NMFS sighting data collected from ice camps in 1978, probably the most representative year because of nearly continuous survey effort, showed that calves were present throughout the migration period. However, the hypothesis that there is a sex-age segregation is so widely contended by Eskimos living along the northwest coast of Alaska that we believe it has basis in fact.

From Point Barrow, bowheads travel northeastward along an offshore route to the eastern Beaufort Sea, where the first individuals arrive by early to mid-May (Fig. 5). We have observed the whales departing from Point Barrow northeastwardly toward Banks Island at an oblique angle to the Beaufort Sea coast, and even though there are often less extensive leads closer to the coast than those offshore we have never seen whales in them. In April and May 1979 during flights conducted to 330 km offshore in the western Beaufort Sea, bowheads were only observed offshore, though small leads were common nearshore (Ljungblad¹¹).

Braham and Krogman (footnote 1) and Fraker¹² independently proposed the hypothesis that bowheads and white whales follow a far offshore route while migrating through the Beaufort Sea during spring. Support for this comes from the following evidence:

1) NOAA satellite imagery of the Beaufort Sea ice cover shows the recurring east-west shear zone in offshore waters, with extensive development of interconnecting leads north of the shear zone (Fig. 3; Marko, 1975; Fraker 1979). These leads in the northern Beaufort Sea are the only avenues apparently available to whales during much of the spring migration period. Nearshore waters of the southern Beaufort Sea are covered by a broad sheet of landfast ice during spring, and the pack ice immediately seaward of the landfast ice usually contains very little open water.

2) No bowheads have been sighted nearshore in the western Beaufort Sea during spring surveys conducted from 1976 to 1979. Instead, all surveys (out to 330 km) indicated that the whales were moving well offshore (Braham and Krogman, footnote 1; Braham et al., footnote 3; Ljungblad, footnote 11).

3) The headings of bowheads observed traveling in leads northeast of Point Barrow are directed northeast and east (Braham et al., footnote 3; Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980), which would take them well offshore and essentially directly to Banks Island.

4) Fraker (1979) observed white whales migrating through leads up to 600 km north of the coast in the Canadian Beaufort Sea in May and June 1977. Results of systematic surveys conducted during June 1974-77 showed that both bowhead and white whales were distributed similarly offshore in the Canadian Beaufort Sea (Fraker, 1979); this implies that both species follow a similar route.

5) Some bowheads arrive near the west coast of Banks Island and Amundsen Gulf more than 2 months before they arrive in the Mackenzie River delta area (Sergeant and Hoek, 1974; Fraker, footnote 12; Fraker and Bockstoce, 1980).

6) Alaskan Eskimo whalers have never hunted bowheads in the Beaufort Sea in the spring; instead, they wait until autumn (Brower, 1942; Marquette, footnote 2).

7) Yankee commercial whalers overwintering at Herschel Island, Yukon Territory, along the Beaufort Sea

coast, tried unsuccessfully to whale from the ice edge during spring (Cook, 1926; Bodfish, 1936; Bockstoce, 1977; Fraker and Bockstoce, 1980).

The earliest known sighting of bowheads in the southeastern Beaufort Sea occurred 6 May 1979 when two bowheads were observed south of Banks Island¹³ (Fig. 4). Two bowheads were observed in a polynya west of northern Banks Island 8 May 1978 by pilots from the Naval Arctic Research Laboratory, Barrow, Alaska. Six bowheads were observed 14 May 1974 in leads just west of Banks Island; but none were seen during surveys conducted there 21-24 April and 1-5 May 1974 (Fraker et al., 1978) or 13 May 1978 (Braham et al., 1979). One bowhead was observed in western Amundsen Gulf 18 May 1977 and two 21 May 1977 about 90 km south-southwest of Sachs Harbour, Banks Island (Fraker, 1979). These sightings show that bowheads can reach Amundsen Gulf by early May.

At the time that early migrating bowheads are moving through the Beaufort Sea, the shear zone and the leads to the north offer the only apparent avenues available. Such whales, traveling northeastwardly, would eventually intercept the north-south lead west of Banks Island (Fig. 3, 5, 6). Once in this lead, the whales can travel south to Amundsen Gulf. All May sightings of bowheads support this hypothesis (Fig. 4). During late May and June, leads form farther south in the ice cover, and thus it is possible for late-migrating whales to travel there (Fig. 5, 6). Sightings made during mid-to late June include some bowheads in the southern Canadian Beaufort Sea (Fig. 4). Fraker (1979) found migrating white whales in the northern Beaufort Sea in late May and early June 1977; later in June he found them farther south.

Some bowheads in the western Arctic population may not complete the spring migration into Canadian waters; they may spend the summer months in the northern Chukchi Sea and/or western Beaufort Sea. A few Eskimo whalers at Barrow state that occasionally

¹¹Ljungblad, D. 1979. Investigations of the occurrence, population density, and behavior patterns of endangered whales in the vicinity of the Beaufort Sea lease area. Unpubl. final rep. for the Bureau of Land Management, 20 p. Naval Ocean Systems Center, San Diego, CA 92152.

¹²Fraker, M. A. 1977. The 1976 white whale monitoring program, Mackenzie Estuary, N.W.T., Unpubl. rep., 73 p., by F. F. Slaney & Co., Ltd., Vancouver, B.C., for Imperial Oil Ltd., Calgary, Alberta.

¹³D. Andriashek, biologist, Canadian Wildlife Service, 9942-108 Street, Edmonton, Alberta T5K 2J5 Canada. Pers. commun.

bowheads are seen near Point Barrow during summer, and some have been seen feeding east of Point Barrow close to shore (Braham et al., footnote 3).

Effect of Ice Cover on Migration

Ice plays a major role in the ecology of Arctic marine mammals (Fay, 1974), including bowhead whales, the most pagophilic (ice-loving) of baleen whales. Sea ice covering the Chukchi Sea begins to advance southward in early October from the limit of its maximum summer retreat near lat. 72° - 74° N, and extends south over the entire Chukchi Sea and the northern Bering Sea from January into June (Shapiro and Burns, 1975). Pack ice is present during winter and spring over most of the intercontinental shelf of the northern and eastern Bering Sea, but occurs infrequently in the southwestern Bering Sea. During late winter and early spring, at the initial stages of spring migration, bowheads are found in waters with 35-50 percent ice coverage (Brueggeman, footnote 6). Brueggeman (footnote 6), reported observing early spring bowhead concentrations in two areas, one west-southwest of St. Lawrence Island and the other west of St. Matthew Island (Fig. 4). He concluded that a corridor of 35-50 percent ice cover occurs persistently from March to May between these islands, and this apparently provides enough open water for whales to migrate through the pack ice each spring.

The pack ice in spring north of St. Lawrence Island and throughout the northeastern Bering Sea is usually medium to thick, with 70-100 percent coverage (Fay, 1974; Shapiro and Burns, 1975; Braham et al., footnote 3). Driven by late spring winds and strong ocean currents converging west of St. Lawrence Island from the central Bering Sea and Gulf of Anadyr (Coachman et al., 1975), the pack ice breaks up and moves northeastward through the Bering Strait. This results in ice coverage of <50 percent in the northwestern Bering Sea, conditions which bowheads take advantage of during migration.

North of the Bering Strait spring ice conditions change drastically. A large, wedge-shaped flaw zone with many



Figure 6.—NOAA satellite image of ice conditions in the eastern Chukchi and Beaufort Seas, 30 May 1977. Light areas are ice, dark areas are water or thin ice (newly refrozen lead).

small leads occurs as a result of strong northeast winds during the winter and early spring (Shapiro and Burns, 1975). Bowheads apparently select the most persistent of these leads, but so few sightings have been made here that we have had to estimate their route based upon the recorded bearings of whales near the Bering Strait. Some whales may deviate eastward from our hypothesized heading of 35° - 45° true to enter nearshore leads that sometimes occur in outer Kotzebue Sound and near Kivalina (Fig. 2).

From Point Hope to just north of Cape Lisburne the shifting pack ice often results in extensive areas of open water up to 50 km offshore. This means that the whales are not restricted to nearshore areas. Farther west and north, however, the number of offshore leads diminishes. In contrast, northeast of Cape Lisburne the nearshore lead adjacent to the landfast ice opens in

April. As the whales pass Cape Lisburne, their direction of travel, which we determined using a theodolite, was 45° - 50° true (Rugh and Cubbage, 1980). At Cape Lisburne, the bowheads apparently adjust their direction of movement to follow the northeasterly nearshore lead that parallels the coast. Although many leads extend northward near Cape Lisburne, it seems that at Cape Lisburne the whales adjust their direction of movement to follow the only persistent lead that continues to Point Barrow. Since 1976, NMFS scientists have not seen any bowhead whales outside the nearshore lead from northwest of Cape Lisburne to Point Barrow, but they have been seen farther offshore in areas west and south of Cape Lisburne.

As the whales approach Point Barrow, the nearshore lead narrows (Fig. 7), and the movement of most whales is correspondingly constricted. The



Figure 7.—Photograph taken 10 May 1977 of the nearshore (shorefast ice) lead which occurs each spring along the northwestern coast of Alaska from Point Lay to Point Barrow.

NMFS has exploited this bottleneck effect during studies designed to census the population. Because no whales have been seen offshore to the west, we have concluded that essentially the entire population migrates past Point Barrow in the nearshore lead (Braham et al., footnote 3; 1979).

Northeast of Point Barrow the shear zone and extensive lead system in the northern Beaufort Sea permit the whales to travel to the vicinity of Banks Island and the Amundsen Gulf region during May and early June. Restriction of ice near Point Barrow and development of offshore leads northeast of the Point provide the migration pathway, a result of converging water masses from the Chukchi and Beaufort Seas and shifting winds, generally from the east and northeast. It is probably advantageous for whales to use these recurring leads, as opposed to those in the southern Beaufort Sea where there is less ice movement and where the availability of open water is less predictable.

A detailed study of the development of these leads in the eastern Beaufort Sea during the spring migration period of bowheads is available only for 1977 (Fraker, 1979). In April, open water became extensive in the Bering Sea and leads were well developed in the Bering

Strait and Chukchi Sea (Fig. 3a). In the Beaufort Sea the shear zone was present, and a limited number of leads was apparent; the Amundsen Gulf polynya was also beginning to develop. Striking changes in the ice cover occurred in May 1977. Off the northwestern Alaska coast, there were large expanses of open water (Fig. 3b, c). Very extensive lead complexes developed in the ice cover of the northern Beaufort Sea, while the southern portion remained largely intact. The Banks Island lead became prominent in May, as did the Amundsen Gulf polynya. By month's end, the pack ice in the northern Beaufort Sea was a maze of leads and there was much open water west of Banks Island and in Amundsen Gulf (Fig. 6). The nearshore lead lying north of the Tuktoyaktuk Peninsula was well established by this time, but it did not extend west of the Mackenzie River delta region.

Conclusions

The spring migration of the western Arctic population of bowhead whales from the Bering Sea to the Beaufort Sea occurs from April through June. The availability of open water dictates the pathway taken during their northward migration. The only persistent leads

which occur in the Bering and Chukchi Seas correspond with traditional places where U.S. and Siberian Eskimos have hunted for bowheads each spring, and where the whales have been consistently observed during our 4 years of research. The hypothesis that bowheads migrate in leads other than those along the northwest coast of Alaska, such as along the north side of Siberia (Chukchi Peninsula) seems implausible because of extensive, persistent ice cover. An offshore migration of bowhead whales west of Barrow, Alaska, is also unlikely and therefore we are confident that essentially the entire western Arctic population can be censused over a short period of time each spring near Point Barrow.

Bowhead whales do not migrate nearshore during spring in the Beaufort Sea. Although some open water is available in the southern Beaufort Sea, offshore leads appear to provide the only suitable habitat for migration to Canadian waters. Whether some bowheads do not complete the migration into the Canadian Beaufort Sea has not been confirmed.

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Migration of Bowhead Whales Past Cape Lisburne, Alaska

DAVID J. RUGH and JAMES C. CUBBAGE

Introduction

Cape Lisburne is one of the most striking promontories along the east coast of the southern Chukchi Sea bordering the bowhead whale, *Balaena mysticetus*, spring migratory route. These whales are known to pass northeast along the Arctic coast from Point Hope to Point Barrow as they migrate

from their wintering areas in the Bering Sea to their summer habitat in the Beaufort Sea. Presumably they follow the coastal contour to take advantage of the sea ice shear zones which are generally associated with the shoreline.

In the past, Eskimo whalers seasonally used the now extinct village of Wevok near the Cape Lisburne Air Force Station. They often watched for

whales from the westernmost bluff known as Alokut or "The Jaw". This 280 m high bluff has an abrupt western face providing whalers an excellent overview of a great expanse of ocean as far south as Point Hope and an unobstructed view to the west and north (Fig. 1, 2).

A pilot study was made during 5-17 May 1977 to investigate the feasibility of a systematic bowhead whale research effort at Alokut. The wide viewing perimeter, persistently open polynyas (areas free of sea ice), and the position of the Cape relative to the migratory corridor encouraged us to take



Figure 1.—Alokut, the westernmost hill at Cape Lisburne, Alaska, drops abruptly into the Chukchi Sea. Just under the crest of the hill, an observation site was established to study bowhead whales as they passed north on their spring migration to the Beaufort Sea. Photograph by David Rugh, NMFS.



Figure 2.—Bowhead whales migrate past Cape Lisburne, Alaska, following leads or holes in the sea ice. Here, David Rugh is studying openings half way to Point Hope, which is on the horizon to the right. Photograph by Katherine Hazard, NMFS.

advantage of the site as a whale observation station (Braham et al., 1979). Totals of 49 bowheads and 155 white whales, *Delphinapterus leucas*, were seen during 73 hours of good to excellent visibility. The rate of sightings steadily declined through the 13-day watch suggesting that a pulse of whales had just passed. Except for fog and high winds, the viewing platform seemed ideal. In over 40 instances bowheads were seen breaching: This was more than might be expected based on observations made elsewhere. This high incidence of breaching was worth further investigation.

The objectives of the whale watch effort in 1978 were to: 1) Delineate the onset and termination of the bowhead whale spring migration through the nearshore leads west of Cape Lisburne; 2) count the population migrating past the Cape; 3) evaluate factors that affect the ability of observers to count whales, particularly distances whales pass offshore and visibility relative to weather; and 4) maintain records of whale behavior for general biological interest.

Methods

Four researchers arrived at Cape Lisburne on 1 April 1978. During the following week, a camp was established

by digging caves in snow banks of a protected vale near the westernmost bluffs of Alokut. In early May an unseasonal thaw made it imperative to use tents. Systematic watch efforts began 2 April and were maintained whenever weather and light allowed until the study was terminated on 7 June because of persistent fog.

Observations were made from four sites, depending on the height of the cloud ceiling. The sites ranged in altitude from 100 to 281 m on the west side of Alokut.

Between 2 April and 7 June, 691 hours of systematic watch were conducted, 617 during fair to excellent conditions (Fig. 3). Low clouds and high winds prevented work 32 percent of the time, and fog occluded parts of the open leads 54 percent of the time. Winds frequently rose above 80 km/hour in exposed areas. Temperatures ranged from -26° to 9°C . Initially, darkness restricted the daily watch to less than 18 hours/day, but by 10 May a 24-hour watch was put into effect.

Distances to whales sighted and the edges of leads were determined with a theodolite whenever possible. Azimuth and zenith angles were converted into a coordinate system to measure whale positions relative to the ice and shore as well as vectors of whale travel. Sight-

ings of whales were categorized as: 1) Initial sightings if the observer had reasonable confidence the whale had not been recorded yet; 2) conditional duplicates if the observer was unsure whether or not the whale had been previously recorded; 3) definite duplicates; and 4) tentative sightings if an occurrence could not be positively identified as a bowhead whale.

Results and Discussion

Census

From 2 April to 7 June, 280 bowhead whales were sighted from Cape Lisburne (Table 1). This count included 37 conditional duplicate sightings. An adequate evaluation of whale sizes and a count of calves were not possible. All sightings made during fair to excellent observation conditions were calculated on a whale-per-hour basis. These sighting rates were used to interpolate the number of whales passing during periods of unacceptable or poor conditions. By multiplying the rate of whales per hour by 24, we estimated the number that passed per day. According to these calculations, 478 bowheads migrated within 15 km of Cape Lisburne between 10 April and 7 June (Fig. 4). This estimate is considerably lower

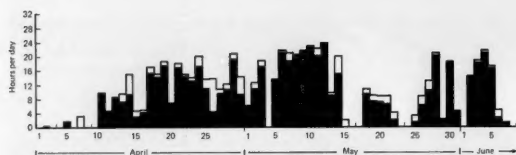


Figure 3.—Bowhead whale observation effort at Cape Lisburne, Alaska, April-June 1978. Upper box indicates number of hours spent on watch per day; shaded area shows number of hours spent in fair to excellent visibility.

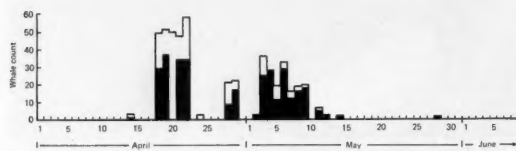


Figure 4.—Bowhead sightings from Cape Lisburne, Alaska, April-June 1978. Shaded area indicates actual counts; upper (unshaded) bars are estimated numbers based on daily rates of all sightings made during fair to excellent conditions and extrapolated to cover periods of poor visibility.

than that made at the Point Barrow census stations (Braham et al., 1979) because: 1) The view from Alokut was frequently occluded during periods when it was assumed many whales were passing; 2) whales approached Cape Lisburne from the southwest rather than from the south or along the shore, which meant most traveled farther offshore than was expected; and 3) there was difficulty in covering the entire field of view with only one or two observers per watch.

To check the accuracy of duplicate designations, timing and position of whale blows (surfacing) were recorded as opportunity allowed. By plotting these coordinates on a chart, an evaluation of whale tracklines could be made (Fig. 5). Each trackline represents the course of a single whale as identified by the observer in the field; however, abrupt turns, back-tracking, and unrealistic speeds found in some cases suggest that the observer was actually watching more than one whale. This makes us suspect the accuracy of "duplicate" designations. Of 26 sightings considered to be duplicates during trackline studies, 35 percent appeared to have been inaccurately designated in the field.

Rate of Travel

An average swimming speed for undisturbed migrating bowhead whales was calculated at 4.7 ± 0.6 km/hour

(2.9 ± 0.4 mph), based on time between nine pairs of bearings which ranged from 30 to 107 minutes. To maximize the accuracy of our calculation, we included only observations that continued

Table 1.—Summary of bowhead whale sightings at Cape Lisburne, Alaska, 1978.

Date	Observation time (hr:min)	Time in fair-exc. conditions	Counts (maximum)	Rate ¹ (whales/hour)	Estimated total ²
April	2 0:10	0	0	—	0
	3 0	0	0	—	—
	4 0	0	0	—	—
	5 1:30	1:30	0	0.0	0
	6 0	0	0	—	—
	7 3:00	0	0	—	—
	8 0	0	0	—	—
	9 0	0	0	—	—
	10 9:30	9:30	0	0.0	0
	11 4:30	4:30	0	0.0	0
	12 8:30	8:30	0	0.0	0
	13 9:25	7:34	0	0.0	0
	14 14:41	9:13	1	0.11	2.6
	15 4:27	3:03	0	0.0	0
	16 4:38	4:08	0	0.0	0
	17 16:20	15:20	0	0.0	0
	18 14:45	14:08	29	2.05	49.3
	19 18:25	17:15	37	2.14	51.5
	20 6:44	4:30	2	—	49.3
	21 17:50	17:20	34	1.96	47.1
	22 14:32	14:12	34	2.39	57.5
	23 14:00	13:30	0	0.0	0
	24 20:00	19:00	2	0.11	2.5
	25 13:15	11:05	0	0.0	0
	26 13:40	4:10	0	0.0	0
	27 10:35	9:47	0	0.0	0
	28 12:00	10:20	9	0.87	20.9
	29 20:20	18:45	17	0.91	21.8
	30 14:05	9:20	0	0.0	0
May	1 6:05	4:55	0	0.0	0
	2 12:30	11:00	1	0.09	2.2
	3 18:35	16:53	25	1.48	35.5
	4 0	0	0	—	27.4
	5 13:45	13:45	11	0.80	19.2
	6 21:45	21:30	29	1.35	32.4
	7 21:02	18:33	12	0.65	15.5
	8 20:30	20:30	16	0.78	18.7
	9 21:15	21:15	12	0.56	13.6
	10 23:20	23:20	0	0.25	0
	11 22:10	20:10	5	0.25	6.0
	12 23:30	23:30	2	0.09	2.0
	13 9:25	9:10	0	0.0	0
	14 20:00	14:30	1	0.07	1.7
	15 2:00	0	0	—	—
	16 0	0	—	—	—
	17 0	0	—	—	—
	18 10:45	9:45	0	0.0	0
June	19 8:50	7:45	0	0.0	0
	20 8:20	7:45	0	0.0	0
	21 8:20	6:30	0	0.0	0
	22 4:05	2:00	0	0.0	0
	23 0	0	—	—	—
	24 0	0	—	—	—
	25 3:00	1:49	0	0.0	0
	26 8:19	6:09	0	0.0	0
	27 13:00	10:30	0	0.0	0
	28 20:41	20:36	1	0.05	1.2
Total	29 2:00	2:00	0	0.0	0
	30 18:25	18:25	0	0.0	0
	31 4:25	4:25	0	0.0	0
	1 0	0	0	—	—
	2 14:07	14:07	0	0.0	0
	3 19:00	18:25	0	0.0	0
	4 21:45	20:35	0	0.0	0
	5 17:05	16:56	0	0.0	0
	6 4:50	2:45	0	0.0	0
	7 1:02	1:02	0	0.0	0

¹Rate of sightings is based on counts of whales seen during fair to excellent conditions divided by the respective hours. All conditional duplicates and tentative sightings are included.

²Estimates include interpolations for days without fair visibility.

for more than 30 minutes and excluded bearings designated as approximate, as well as the aforementioned irregular tracklines.

Timing of the Migration

At 1335 hours on 14 April a tentative bowhead sighting was made at Cape Lisburne. On 18 April, at 1300 hours, the first pulse of bowheads began passing the Cape. Between 18 and 22 April 136 bowheads were recorded. Based on a calculated travel rate of 4.1 to 5.3 km/hour, the tentatively sighted whales of 14 April, traveling the 460 km between Cape Lisburne and Point Barrow in 87 to 112 hours, should have passed Point Barrow between 0400 hours on 18 April and 0600 hours on 19 April. The first whales seen on 18 April at Cape Lisburne should have passed Point Barrow between 0400 hours on 22 April and 0500 hours on 23 April.

At Point Barrow, the first bowhead whale sighting of the season was made at 0223 hours on 20 April. This was between the expected time of arrival of the bowhead whale tentatively sighted from Cape Lisburne on 14 April and the beginning of the pulse of whales seen on 18 April. Either the tentative sighting was actual, or the first whales seen at Point Barrow were not seen at Cape Lisburne.

It is evident that the migrating bowheads began passing Cape Lisburne between 14 and 18 April. On 17 April, a lead began to open between Point Hope and the Cape. Before the lead developed opposite the observation site, whales were seen traveling north surfacing in small holes and cracks. Visibility had been irregular on the preceding days—most of 15 and 16 April was lost to observation effort due to fog and heavy snowfall. Whales may have passed unobserved during such periods.

By 15 May most of the whales had passed Cape Lisburne. At Point Barrow the last pulse of whales ended on 17 May followed by a low rate of sightings until 30 May. At Cape Lisburne, 99.3 percent of the sightings occurred between 18 April and 14 May. During a comparable 27-day period at Point Barrow (22 April to 18 May), 96.8 percent of the sightings occurred. Based on travel rates established from bearings

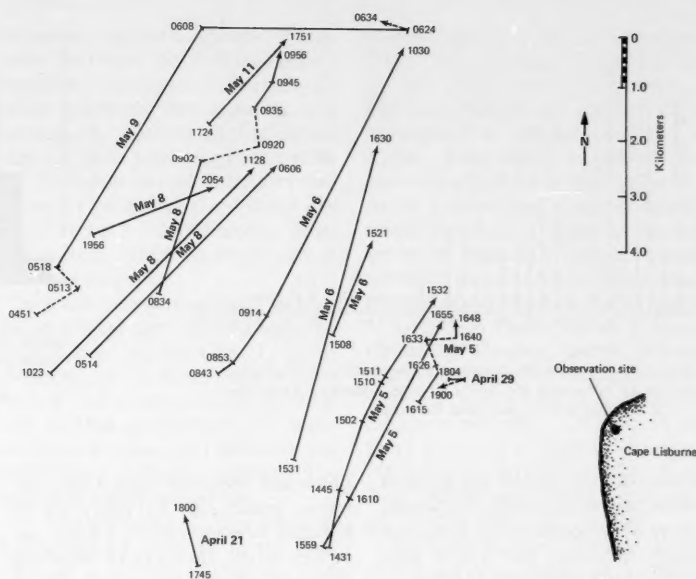


Figure 5.—Positions of bowhead whales relative to the observation station at Cape Lisburne, Alaska, April-June 1978. Time, date, and direction of travel of each sighting are recorded.

on migrating whales, bowheads can be expected to travel from Cape Lisburne to Point Barrow in 3.6 to 4.7 days, which compares well with the 4-day lag in migration dates between these two sites. The compatibility in the distribution of sightings between Cape Lisburne and Point Barrow makes it evident that the bulk of the bowhead population passed during the study period.

Distance Offshore

Of 170 bearings recorded, the average whale sighting distance was 4.5 km from observation sites at Cape Lisburne. The maximum recorded distance was 14.8 km, which approaches the outer limit of reliable visibility under excellent conditions. All of the sightings made at 14 to 15 km occurred on a single day, 22 April. It is unknown how often whales passed at this distance on other days when observation conditions were inferior, nor is it known how many whales traveled past Cape Lisburne beyond 15 km. Poor weather occurred during periods when aerial surveys were planned for assessing the offshore distribution.

Positions of bowheads in the leads were calculated as a ratio of the whale to the pack ice distance and the lead width with all bearings relative to a common azimuth. Of 19 ratios, all whales were sighted beyond the middle of the lead, and 11 (58 percent) were within 20 percent of the lead width from the pack ice edge. Bowheads thus appeared to prefer the farshore edge of the lead as they passed Cape Lisburne. As the season progressed, the pack ice and whale sightings tended to be farther offshore. This tendency is not an artifact of increased observer ability, as some of the greatest distances to sightings were recorded early in the season. In spite of complexities due to fog and irregular ice conditions, the above data suggest that whales passing Cape Lisburne did not follow the coast even when distinct leads were available there; They followed a course that kept them on the west side of visible leads and in offshore polynyas.

Direction Headed

Except when milling, all bowheads passed Cape Lisburne on a northeaster-

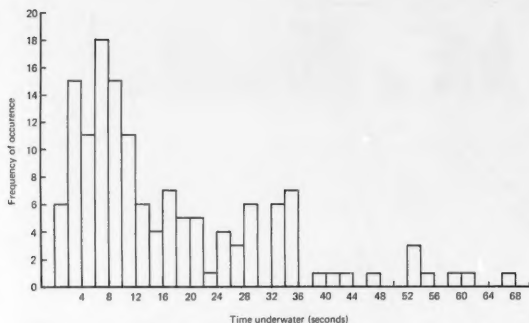


Figure 6.—Frequency of blows within bowhead whale dive series as observed at Cape Lisburne, Alaska, April-June 1978. Milling whales were not included.

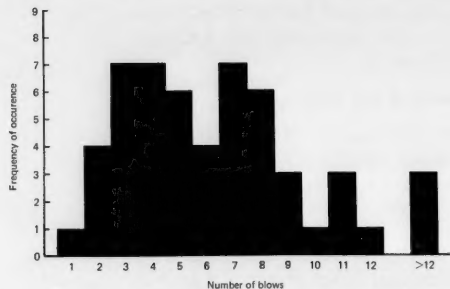


Figure 7.—Dive timings measured as bowhead whales passed Cape Lisburne, Alaska, April-June 1978.

ly course. No correlation was apparent between bearing and distance to whales offshore when compared on a common azimuth, indicating that whales were not effectively changing direction as they passed Cape Lisburne. This orientation was consistent with observations made during aerial surveys (Braham et al., 1979).

Most whales were seen along common corridors which varied according to ice conditions. There was a strong tendency for whales to follow each other even to the point of selecting common breathing sites among scattered holes and along the far shore of the open lead. There were eight recorded incidences involving 52 whales following each other. Synchronous swimming, where two or more animals surfaced and dove together, was observed on seven occasions.

Behavior

Systematic behavior notes were kept on 15 whales totaling 5.5 hours of observation time during the study period. Recorded behavior included milling (groups of whales seen turning and rolling close together), loitering (single whales making frequent turns), breaching, and fluke slapping.

On three occasions whales deviated from their migratory course to mill or loiter. Milling episodes involved two or three animals and may have been associated with courtship or mating. Usually rolling, contact, and flippers were visible in such sequences.

Sixty-five (23 percent) of all

bowheads observed from Cape Lisburne breached. As many as 39 breaches were recorded in a single unbroken series. Instances of breaching decreased through the season. On 26 occasions fluke slapping was noted with a maximum of 33 slaps in a single series. Instances of group breaching and fluke slapping were observed. On 21 April, a single bowhead was seen breaching and fluke slapping. After at least 20 breaches, two other bowheads approached the first, breaching and fluke slapping as they arrived. Approximately 45 minutes after the first whale was noticed, a fourth appeared. All four whales moved north while breaching and fluke slapping. Over 86 breaches were observed during this period. On 22 April, two bowheads were seen rolling and swimming close together as they migrated past Cape Lisburne. Approximately 1 hour after this pair was seen, a third whale arrived and two bowheads were seen fluke slapping simultaneously. On the same day, two other whales breached together and one made numerous fluke slaps. One animal appeared to be smaller than the other. The high frequency of breaching and fluke slapping in the Cape Lisburne area may be a function of an environment conducive to the courtship or other communicatory roles such behavior may play.

Visual Cues

There seemed to be little consistency in circumstances surrounding the sightings of blows by surfacing whales. Of

237 observations where the visual cue that first alerted an observer to a whale was recorded, 56 were whale blows; the others were whales' black backs or wakes caused by their motions. Some whales passed without making a visible blow, whereas others made distinct blows each time they surfaced. For example, a whale was observed to surface 6 times with no visible blow; yet within half an hour, a second whale showed a distinct blow on each of 11 surfacings. This inconsistency makes it difficult to calculate the likelihood of sighting a blow relative to the rate of surfacings.

We counted the number of surfacings whales made in 53 dive series (Fig. 6). Although the distribution was irregular, it suggests that bowheads generally blow between two and nine times in a series.

Dive Times

We defined a "series dive" to be any submergence of less than 75 seconds within a blow sequence. Dives that lasted longer were considered to be "sounding dives." This distinction was based on the distribution of dive timings (Fig. 7). Only three sounding dives were recorded, lasting 395, 437, and 524 seconds. The 145 recorded series of dives ranged in length from 1.3 to 67.8 seconds with a mean of 17.9 ± 2.3 seconds. From 50 samples of dives when no breaches occurred, time underwater ranged from 2.3 to 53.5 seconds. Mean dive length for this series was 11.6 ± 2.4 seconds.

Surface Times

The length of time a whale was visible to the observer at each blow was recorded. Of 112 recordings for non-breaching animals, surface times ranged from 1.6 to 16.5 seconds. Mean time at the surface was 6.1 ± 0.5 seconds. Of 36 breaching animals, surface times ranged from 1.9 to 10.3 seconds with a mean of 4.1 ± 0.6 seconds.

Summary

Between 2 April and 7 June, 280 bowhead whales were counted from the Cape Lisburne research site at Alokut during 691 hours of systematic observation effort; 99.3 percent of these whales were seen between 18 April and 14 May. This compares with sightings made at Point Barrow where 96.8 percent of the whales passed between 22 April and 18 May. This 4-day lag in sightings between the two observation sites compares favorably with the estimated 3.6 to 4.7 day travel time ($4.1\text{--}5.3$ km/hour calculated rate of travel for bowheads passing Cape Lisburne).

Using interpolations to estimate the number of whales passing during periods of poor visibility, approximately 478 bowheads passed the Cape within 15 km during the spring migration. The average offshore recorded distance was 4.5 km. Whales were seen as far as 14.8 km, the outer limit of visibility

during excellent conditions. An unknown portion of the population passed beyond the viewing range. Virtually all of the bowheads were traveling in a northeasterly direction as they passed Cape Lisburne which suggests a route less dependent on coastal features than on sea ice shear zones and direct line travel toward Point Barrow. Most whales were sighted on the far side of leads and polynyas.

Fog and storms precluded watches during critical parts of the migration, further reducing the Cape Lisburne counts relative to those made at Point Barrow. The viewing area was too large to be covered adequately by one or two observers at a time, and problems with determining duplicate sightings also may have suppressed counts.

A high frequency of breaching and fluke slapping occurred in the Cape Lisburne area relative to records from other sites. Synchronous breaching and milling suggest considerable courtship and/or copulation was taking place. The mean dive time between sounding dives for nonbreaching whales was 11.6 ± 2.4 seconds. The mean recorded time at the surface was 6.1 seconds with a range of 1.6 to 16.5 seconds.

Acknowledgments

Howard Braham, as supervisor of the Arctic Whales Task, NMFS National

Marine Mammal Laboratory, Seattle, Wash., provided guidance and support for this study at Cape Lisburne. Katherine Hazard and Andrew Taber participated in the field research at Alokut. Their ability to perform research in spite of the isolated and severe Arctic environment deserves special credit. Cary Ball, a student at the University of Washington, Seattle, volunteered considerable time to help synthesize and analyze the data. Robert Melby of the NOAA Pacific Marine Environmental Laboratories, Seattle, donated time, equipment, and assistance in developing appropriate surveying and calculator programs. Civilian and Air Force personnel at Cape Lisburne Air Force Station and Elmendorf Air Force Base, Anchorage, Alaska, generously provided us with needed support.

We thank Michael Tillman, George Harry, and Alton Roppel of the NMFS National Marine Mammal Laboratory and the management review branch of the Seattle Laboratory of the NMFS Northwest and Alaska Fisheries Center for reviewing this paper.

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Vessel Survey for Bowhead Whales in the Bering and Chukchi Seas, June-July 1978

MARILYN DAHLHEIM, TERESA BRAY, and HOWARD BRAHAM

Introduction

Prior to the advent of Yankee whaling for bowhead whales, *Balaena mysticetus*, in the Chukchi Sea in 1848, there were an estimated 6,500 bowheads in the Sea of Okhotsk population and 11,700 to 18,000 in the western Arctic population (International Whal-

ing Commission, 1978). By the turn of the 20th century bowheads in the Sea of Okhotsk had been nearly exterminated

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and those in the Bering Sea and Arctic Ocean were reduced to a level that was no longer commercially important (Bockstoe¹).

Townsend (1935) reviewed several hundred logbooks of 19th century whalerships and plotted positions of 5,114 bowhead catches in the Bering Sea and Arctic Ocean from lat. 53° to 73° N, and long. 120° W to 135° E (Fig. 1a, b, c). Catches were recorded from much of the Bering Sea, the majority on the western side, and showed a clear

¹Bockstoe, J. 1978. A preliminary estimate of the reduction of the western Arctic bowhead whale (*Balaena mysticetus*) population by the pelagic whaling industry: 1848-1915. Unpubl. manuscr., 32 p. Prepared for the Marine Mammal Commission, Washington, D.C.

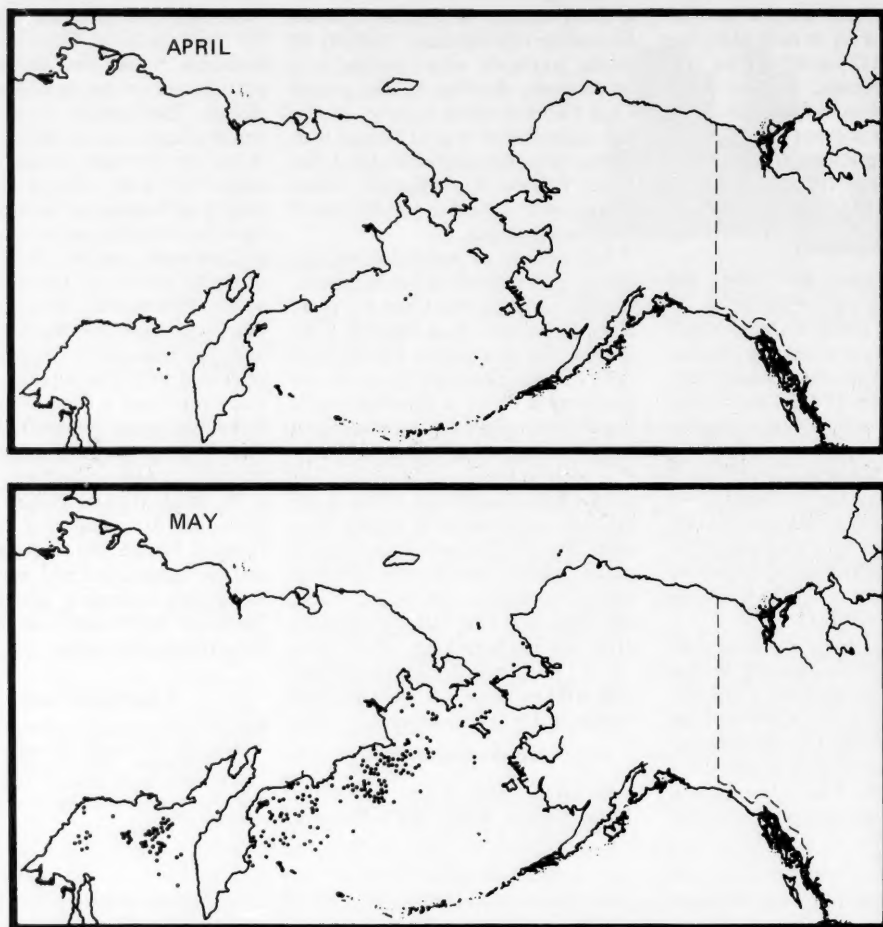


Figure 1a.—Locations where bowheads were taken by Yankee whalers in April and May 1848-1919. Each black dot represents a single harvested whale. Data points summarized from Townsend (1935).

shift northward through the season as animals moved in response to the receding ice. Townsend's (1935) harvest records for the months of June through October indicated that bowheads once ranged from west of Wrangel Island, U.S.S.R., to Amundsen Gulf, Northwest Territories, Canada, and from as far south as the Pribilof Islands west to Cape Navarin, U.S.S.R. These records have served as the major source for understanding bowhead distribution during the period of commercial exploitation, 1848-1919. Townsend's plots, when compared with current knowl-

edge of the distribution of bowheads (Braham et al., 1979; Braham and Krogman²; Braham et al.³), suggest that these whales were killed over a much wider range than they apparently occupy at present.

²Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

³Braham, H., B. Krogman, and G. Carroll. 1979.

In 1978 an estimated 1,783-2,865 bowheads migrated past the National Marine Fisheries Service (NMFS) ice camp census stations near Point Barrow, Alaska (Braham et al., 1979). This estimate was based on counts made in

Population biology of bowhead whale (*Balaena mysticetus*) II: Migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution and life history of white whales (*Delphinapterus leucas*). Unpubl. final rep., OCSEAP Contract R7120807, 118 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

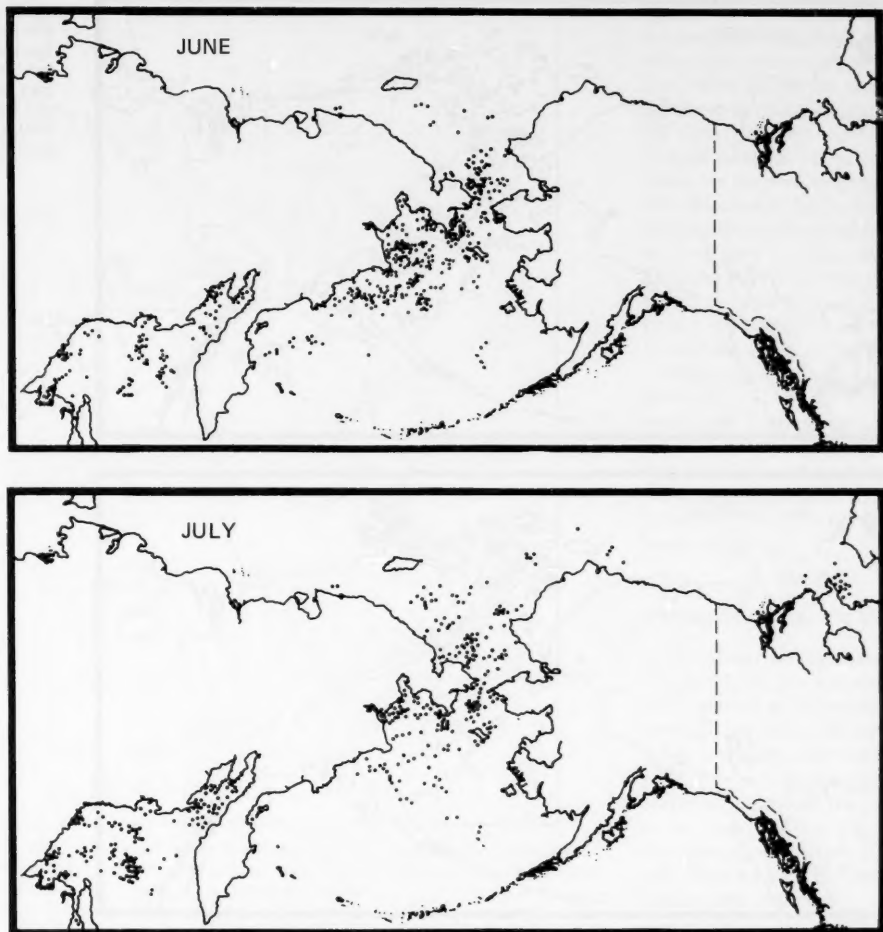


Figure 1b. —Locations where bowheads were harvested by Yankee whalers in June and July 1848-1919 (from Townsend, 1935).

the nearshore lead near Point Barrow from 15 April through 30 May. To evaluate the accuracy of this estimate, it was necessary to determine whether additional whales: 1) Migrated eastward past the ice camps after they closed in June, 2) migrated directly into the western Chukchi Sea in the spring without passing the Point Barrow ice camp, and/or 3) slowly migrated north from the Bering Sea to the central Chukchi Sea with the retreating ice in June and July.

Data collected from aerial surveys flown in 1976 and 1978, corroborated

by data from a land-based study in 1978, strongly suggest that few, if any, whales migrated through leads past Point Barrow after the closure of the ice camps (Rugh and Cubbage, 1980; Braham et al.³, 1980). Two questions remained to be answered before it could be determined what, if any, correction should be applied to the NMFS population estimate: Did any bowheads migrate directly into Soviet waters during the spring of 1978? Did any whales migrate into the central Chukchi Sea with the retreating ice during the summer of 1978 and, therefore, remain un-

accounted for in the spring census at Barrow? To address the first question, ice conditions in the northwest Chukchi Sea were examined (see Discussion). To address the second, a survey was conducted in the Bering and Chukchi Seas in June and July 1978. Results of the survey are reported in this paper.

Also summarized here are survey results from three other vessels on cruises in the Bering Sea and Arctic Ocean during 1978: NOAA research vessel *Surveyor*, Soviet sealing vessel *Zubarevo*, and U.S. Coast Guard icebreaker *Northwind*.

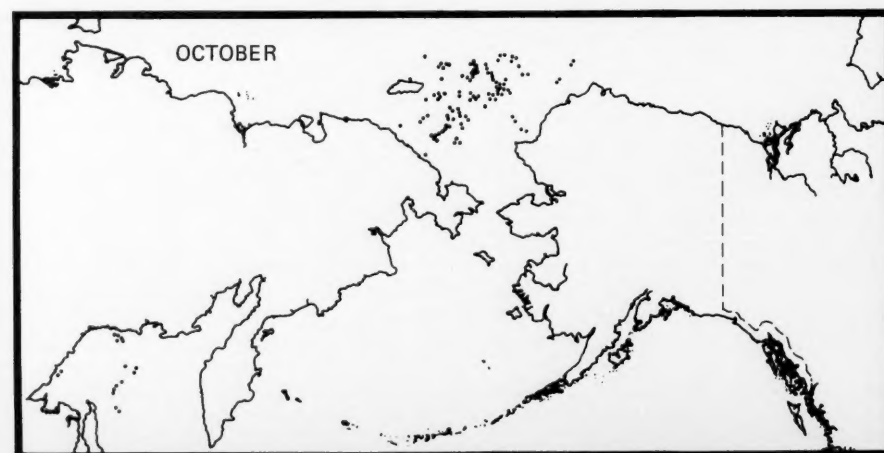
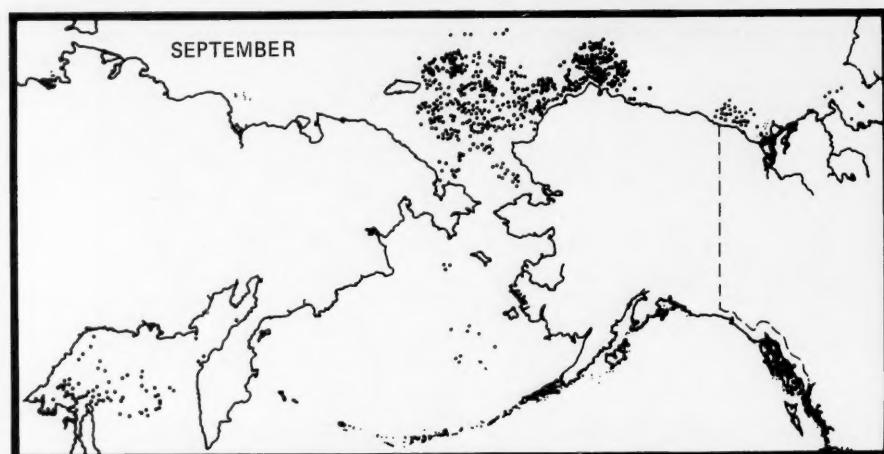
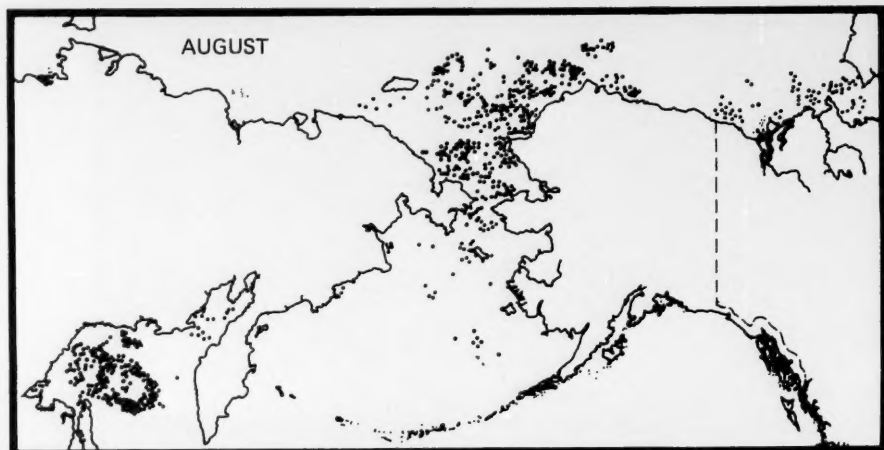


Figure 1c. — Locations where bowheads were harvested by Yankee whalers in August, September, and October 1848-1919 (from Townsend, 1935).

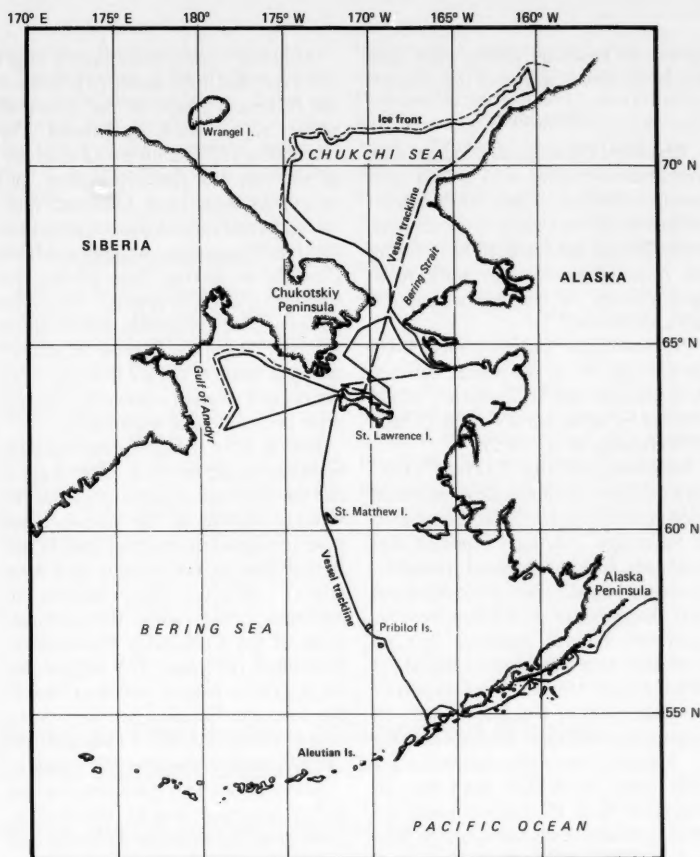


Figure 2.—NMFS bowhead whale study area and vessel survey tracklines north (—) and south (---) during the fishing vessel *Western Viking* survey, 14 June–15 July 1978. Short dashed lines (---) represent the ice front.

Materials and Methods

The survey was conducted from the *Western Viking*, a 33 m fishing vessel based in Dutch Harbor, Alaska. The cruise began in Seward, Alaska, on 13 June and ended in Nome, Alaska, on 15 July 1978 after completion of the transect shown in Figure 2. Permission was obtained from the Soviet government to extend the cruise track to within 19.3 km (12 miles) of the Soviet coast from the Gulf of Anadyr to the north side of the Chukotskiy Peninsula.

From 11 to 15 observers were on-board at various times during the cruise—eight NMFS personnel, four students, and one staff observer from

the Ocean Research and Education Society (ORES), and two representatives of the Alaska Eskimo Whaling Commission. Watches were maintained along the entire survey route, weather permitting. Initially, 4-hour watches were kept by teams of three observers. The southern portion of the survey track was in darkness 3 hours/day, from 0200 to 0500 hours; the northern section had 24-hour daylight. Beginning 26 June, watches were reduced to two observers for 2-hour periods on a 24-hour schedule.

Daily records were maintained of the vessel's position, heading and speed, observers' hours and position on the vessel, weather and sea surface condi-

tions affecting visibility, and an appraisal of visibility. When marine mammals were sighted, the following information was recorded: Sighting cue (i.e., what caught the observer's eye); estimated horizontal angle of the sighting relative to the vessel's heading; estimated distance to the sighting and, whenever possible, perpendicular angle and estimated distance of the animal(s) passing abeam; the number of individuals and their heading and behavior. Once the basic data were recorded, the vessel diverted from its course to approach the animal(s) for closer behavioral observations and for photographs.

When species of special interest were encountered, underwater recordings were made. Signals were transmitted on a VHF carrier back to the vessel where they were received by a Defense Electronics Instrumentation (DEI)⁴ recorder (sonobuoy receiver) and recorded on a Nagra recorder.

Results

Fishing Vessel *Western Viking*

The 31-day survey covered approximately 10,186 km and resulted in observations of an estimated 1,238 cetaceans; 51 sea otters, *Enhydra lutris*; and 4,643 pinnipeds. No bowhead whales were observed, despite nearly ideal observation conditions over much of the survey route, particularly in the northern Bering and southern Chukchi Seas and along the ice edge where bowhead whales were expected.

Analyses of the acoustic recordings from the *Western Viking* cruise are not complete; however, we do not believe bowhead vocalizations were recorded. Recordings were made in the presence of other marine mammals, including Dall's porpoise, *Phocoenoides dalli*; killer whales, *Orcinus orca*; and walrus, *Odobenus rosmarus*; these have been reviewed and do not appear to contain sounds recognizable as bowhead whale vocalizations.⁵

NOAA Research Vessel *Surveyor*

During the period 25 April–15 June 1978 (Cruise I, legs 5 and 6), scientists

⁴Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

⁵D. K. Ljungblad, Naval Ocean Systems Center, San Diego, CA 92152, pers. commun. 1980.

aboard the NOAA ship *Surveyor* surveyed the area from the southern edge of the pack ice in the Bering Sea, including St. Lawrence Island, southerly along the Alaska coast, through Unimak Pass and on to Kodiak, Alaska. Weather was variable; good viewing conditions were prevalent along the ice edge. Throughout the cruise a marine mammal watch was maintained, consisting of one or two deck officers, quartermaster, helmsman, and lookout.

On 7 May 1978 at 0710, a tentative observation of a bowhead whale was made at lat. 61°15'N, long. 172°41'W. At 0835 on the same date, one bowhead was sighted along the ice edge at lat. 61°16'N, long. 172°13'W. Both sightings occurred during the middle portion of the spring migration past the whaling villages. These whales might not have reached the Arctic Ocean until after the spring hunt or closure of the NMFS ice camps.

Sealing Vessel *Zubarevo* (U.S.S.R.)

From March through July 1978 the crew of the Soviet sealing vessel *Zubarevo* hunted pinnipeds from Karaginski Bay (lat. 59°30'N, long. 155°E) north with the receding ice to Wrangel Island. During this 5-month cruise no bowhead whales were seen. On 4 August 1978, Geoff Carroll, NMFS, Seattle, Wash., boarded the *Zubarevo* at Barrow, Alaska. The vessel departed Barrow and proceeded southwest along the ice edge to 37 km northwest of Wainwright, Alaska, where it remained until 13 August, then gradually worked west, to Herald Island. The vessel proceeded south through the Bering Strait to Arakamchechen Island, and on to Gambell, St. Lawrence Island. During this cruise no bowheads were observed though coverage was thorough along the ice front (lat. 70°55'N, long. 160°32'W to lat. 71°57'N, long. 160°59'W).

USCG Icebreaker *Northwind*

The U.S. Coast Guard icebreaker *Northwind* worked in the Beaufort Sea from 15 August to 15 September 1978. Although detailed records on marine mammal sightings were not main-

tained, no bowhead whales were seen during the first 2 weeks of the cruise.⁶

Discussion

Results of the research conducted on four separate cruises in 1978 lead us to conclude that few, if any, bowheads remained in the area south of the ice front in the Bering and Chukchi Seas during the summer months. In addition to these cruises, several factors support this conclusion.

No bowheads were observed along the ice edge or in the waters between Point Barrow and St. Lawrence Island covered by aerial surveys of 8-11 June 1978 (Braham et al. 1980).

Members of the Eskimo communities have commented on bowhead whale modern distribution. The mayor of Savoonga, Alaska,⁷ reported that bowheads were not observed around St. Lawrence Island between late April and early December 1978. Whalers from St. Lawrence Island⁸ reported that no bowheads were seen around the island between early May and the first part of November 1978. Donald Harry⁹, in cooperation with local Eskimos hunting for marine mammals, maintained a shore count for NMFS from May to December 1978. His records noted the absence of bowheads from June to September, though 11 bowheads were seen between 26 September and 21 December 1978 (Braham et al. 1980). The mayor of Little Diomedé, Alaska¹⁰, reported that bowheads had been sighted around the island only in spring and autumn during his lifetime. All Eskimos interviewed stated that bowheads did not occur in the northern Bering Sea during the summer months, except for an occasional animal (Braham et al., footnote 3).

Although considerable survey effort was expended in the southern portion of the historical range of the bowhead whale, no bowheads were found. The cumulative 1978 sighting data from aerial surveys, four research cruises, and interviews with local Eskimos, indicated that this species was not present in the ice-free waters of the southern Chukchi or Bering Seas during the summer of 1978. It appears, then, that bowheads are not present in substantial numbers during the summer months in the areas south of the ice front and may not occupy as great a range as they did prior to commercial exploitation.

Results from the spring and summer bowhead whale research effort suggest that the bowhead population spends the summer months in the Beaufort Sea prior to migrating into the Chukchi and Bering Seas in late autumn and early winter months. Observations of bowhead whales along the northeast coast of the Chukotskiy Peninsula in September 1974 and 1975 suggest that the migration pattern into the Chukchi Sea from the Beaufort Sea may be by way of Herald Island.¹¹ This seems to corroborate Townsend's (1935) data.

Although we feel confident that our survey coverage was as thorough as could be achieved under the limitations of time, personnel, funding, and clearance into Soviet waters, some bowheads may have escaped our detection, moving into Soviet waters between April and June. However, land-fast ice is generally extensive and pack ice heavy along the northern Siberian coast of the Chukotskiy Peninsula northwest of the Bering Strait during spring, as wind is generally from the northeast. It seems unlikely that any persistent leads develop along the Soviet northern coast, and thus few bowheads would be present. This is substantiated by the fact that there are at present no whaling villages along this portion of the Soviet coast, yet in the past there were several along the southern and eastern coasts of the

⁶K. J. Frost, Alaska Dep. Fish Game, 1300 College Rd., Fairbanks, AK 99701, pers. commun. October 1978.

⁷J. Wongitillin, Mayor, Savoonga, AK 99759, pers. commun. to Steven Leatherwood, June 1978.

⁸V. Slwooko, and C. Oozeva, Gambell, AK 99742, pers. commun. to Howard Braham, Summer 1978.

⁹D. Harry, Gambell, AK 99742, pers. commun. to Howard Braham, December 1978.

¹⁰P. Omiak, Mayor, Little Diomedé, AK 99790, pers. commun. to Stephen Leatherwood, 1 July 1978.

¹¹A. A. Berzin, Pacific Scientific Research Institute of Fisheries and Oceanography [TINRO], Tupik Shevchenko, 4, Vladivostok, 690600, U.S.S.R., pers. commun. 16 January 1977.

Chukotskiy Peninsula (footnote 11).

The objectives of the *Western Viking* survey were essentially met. Since no bowheads were sighted, it does not appear that a major correction factor is needed for the spring 1978 population estimate.

Acknowledgments

We gratefully acknowledge Stephen Leatherwood, Hubbs/Sea World Research Institute, who acted as cruise leader for the *Western Viking* expedition. Fellow employees of the NMFS Marine Mammal Laboratory who contributed to the success of this research were Kenneth Balcomb, Camille Goebel, and Patrick McGuire. John Burns (*Zubarevo*); Kathy Frost

(*Northwind*), and Lloyd Lowry (*Surveyor*) from the Alaska Department of Fish and Game, Fairbanks, and Francis Fay (*Surveyor*) of the University of Alaska, Fairbanks, also provided valuable information. Donald Ljungblad (Naval Ocean Systems Center, San Diego, Calif.) skillfully conducted the acoustics research during the *Western Viking* cruise. We are grateful also to Susan Farnham, Victoria Moran, George Nichols, Arthur Seavey, and Gale Ward (ORES), and to the captain and crew of the *Western Viking* for their assistance in maintaining marine mammal watches. Data were also supplied by scientists and crew members of the *Surveyor*. Special appreciation is extended to Conrad Oozeva and Vernon Slwooko (Gambell), Jerry

Wongittilin (Savoonga), and Patrick Omiak (Little Diomed).

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Summer Distribution of Bowhead Whales in the Eastern Beaufort Sea

MARK A. FRAKER and JOHN R. BOCKSTOCE

Introduction

Nearly all bowhead whales, *Balaena mysticetus*, of the western Arctic stock migrate each spring from wintering grounds in the Bering Sea to summering grounds in the eastern Beaufort Sea and Amundsen Gulf where they stay for up to 4 months (Fraker et al., 1978; Fraker, 1979). The whales begin their spring journey soon after ice conditions permit (late April) and they remain on the summering grounds nearly until freeze-up. Although the summering area must be of major significance in the ecology of these animals, little is

known about its geographical extent or the reason for its importance.

Our purpose is to describe the geographical area used by the bowheads during the July-September period (based on the locations of sightings and kills made by commercial whalers near the turn of the century and on recent observations) and to suggest an explanation of the significance of this area to these animals.

Methods

Whaling Ship Observations (1891-1906)

Because there are few recent sightings of bowheads from the eastern Beaufort Sea and Amundsen Gulf, the best information about bowhead distribution comes from logbooks kept by

commercial whalers who operated extensively in this region from 1890 to about 1910 (Bockstoce, 1977). The locations and dates of sightings and captures have been extracted from original logbooks (held by the Whaling Museum, Old Dartmouth Historical Society, New Bedford, Mass.; the Providence [Rhode Island] Public Library; and Harvard University) of vessels operating in the eastern Beaufort Sea from 1891 to 1906 (Table 1). The only logbooks selected were those of cruises which took place entirely in the eastern Beaufort Sea region, and thus were preceded and followed by overwintering in the Arctic. We selected these records to

Table 1.—Vessel, logbook keeper, year, and wintering location prior to cruise of the eastern Beaufort Sea whaling grounds.

Vessel	Logbook keeper	Year	Wintering location
Mary D. Hume	H. H. Bodfish	1891	Herschel Island
Mary D. Hume	H. H. Bodfish	1892	Herschel Island
Newport	H. H. Bodfish	1894	Herschel Island
Newport	H. H. Bodfish	1895	Herschel Island
Mary D. Hume	G. B. Leavitt	1896	Herschel Island
Beluga	H. H. Bodfish	1898	Langton Bay
Beluga	H. H. Bodfish	1899	Baillie Islands
Narwhal	G. B. Leavitt	1903	Herschel Island
Karluk	Unknown	1905	Herschel Island
Alexander	J. A. Tilton	1906	Herschel Island

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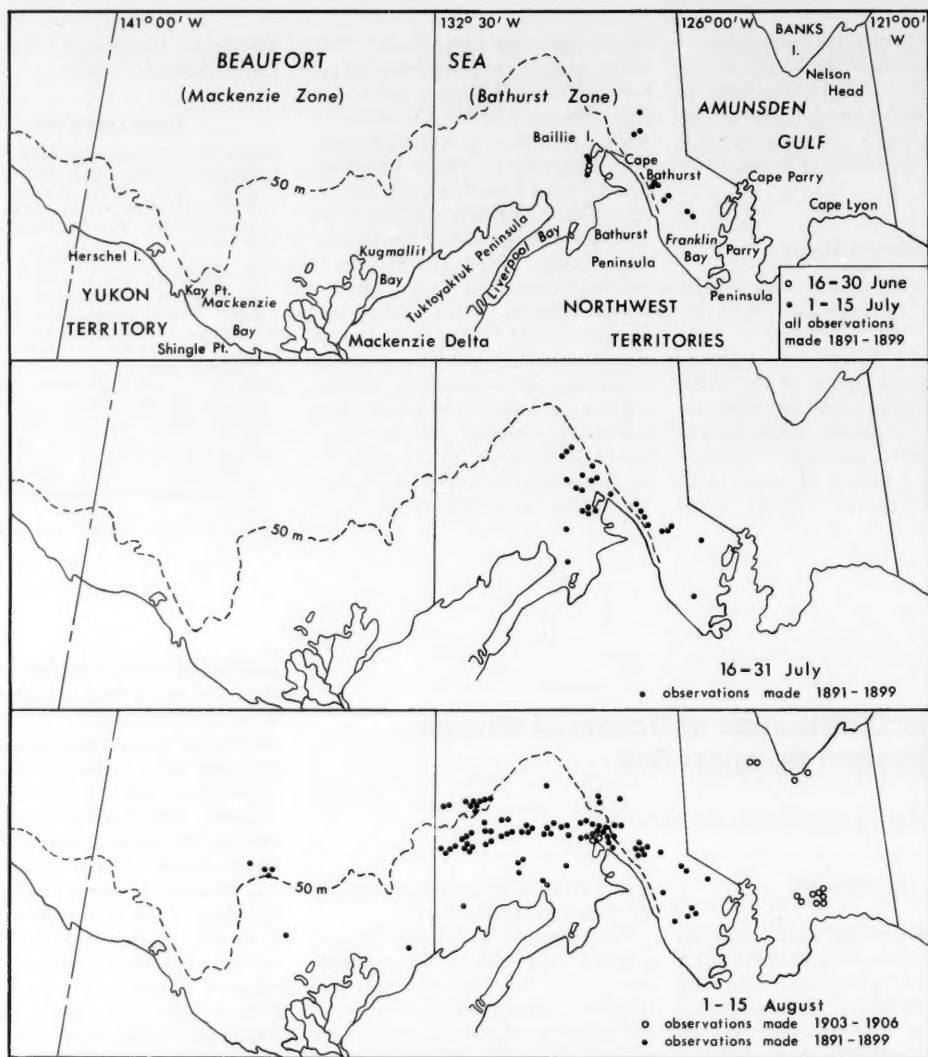


Figure 1. — Locations of bowhead whale observations made from whaling ships, 1891-1906. Each symbol represents an observation of one or more whales.

ensure that the searches by the whalers spanned the greatest possible time period in this region. Because of ice conditions to the west (near Point Barrow, Alaska), vessels from "outside" were unable to arrive in the eastern Beaufort Sea before August; vessels intending to leave the Arctic had to pass Point Barrow by early September (Cook, 1926; Bodfish, 1936; Bockstoe, 1977). We used data from only one cruise per year to minimize biases

which might have resulted from peculiar conditions of particular years. We would have preferred to use data from one cruise from each year of the commercial fishery in the Beaufort Sea, but unfortunately, for certain years, documents meeting our requirements have not survived.

Commercial whalers, when cruising in waters familiar to them, generally determined their position from landmarks. They usually recorded their po-

sition once each day in the logbooks, but under foggy conditions position was determined less often. In plotting data from the logbooks, we sometimes had to estimate the ship's position on a given day using previous and subsequent positions, information on the ship's speed and course, and the recorded water depth. We have firsthand familiarity with the region and believe that most records have been plotted to an approximate accuracy within 20 km

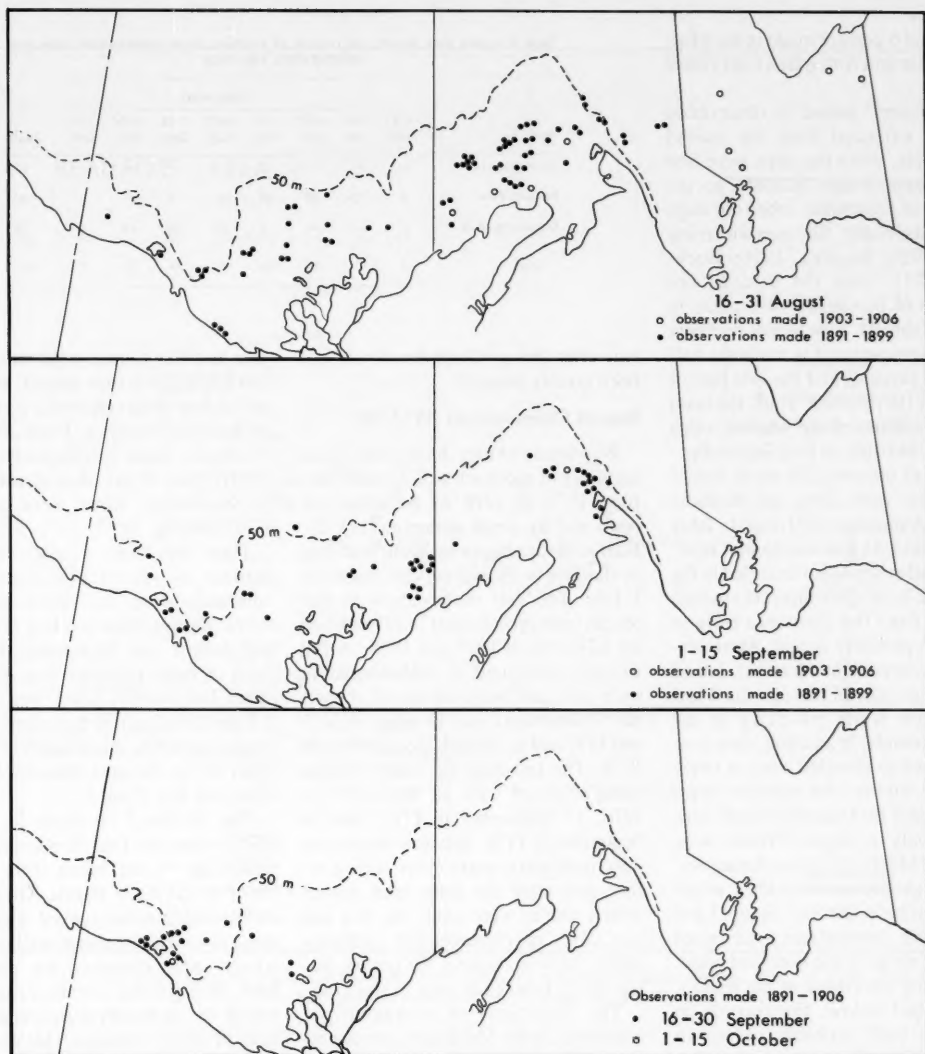


Figure 1.—Continued.

(10 nmi). Observations from uncertain locations were omitted.

Recent Observations (1974-78)

Recently, several persons have recorded sightings of bowheads in the eastern Beaufort Sea, and these data provide additional insight into the whales' use of certain areas and the timing of their movements.

From 1976 to 1978, sightings were recorded on whale sighting forms

supplied to personnel working for Esso Resources Canada Limited on offshore oil and gas exploration projects in and near the Mackenzie River estuary; other sightings were made during aerial surveys of whales in this region. Additional observations were obtained from the field notes of scientists and from interviews with local inhabitants. Most records included date, location, estimated numbers, and direction of movement (if any).

Results

Whaling Ship Observations (1891-1906)

To discuss the observations conveniently, the study region has been divided into three areas: The Mackenzie Zone, the Bathurst Zone, and Amundsen Gulf (Fig. 1). Most (67 percent) of the captures and sightings made from commercial whaling vessels occurred in the Bathurst Zone, with 27

percent and 6 percent made in the Mackenzie Zone and Amundsen Gulf (Table 2).

The whalers' period of observation generally extended from the second week in July, when the ships were first able to leave winter quarters, to the latter half of September, when the ships were made ready for overwintering (Cook, 1926; Bodfish, 1936; Bockstoe, 1977). Most (64 percent) observations of bowheads were made in August (Table 2). Substantial numbers were also encountered in the latter half of July (9 percent) and the first half of September (16 percent). Thus, the main period of activity of the whaling ships was from mid-July to mid-September.

Nearly all observations made before mid-August were from the Bathurst Zone and Amundsen Gulf (Fig. 1, Table 2). After mid-August substantial numbers of whales were also recorded in the Mackenzie Zone. The apparent absence of whales from the latter area early in the season probably is real. Most vessels overwintered at Herschel Island (Table 1) and passed through the Mackenzie Zone while travelling to the whaling grounds; in addition, they usually returned to Herschel once or twice during the summer for supplies or repairs. Whales in Amundsen Gulf were observed only in August. Whales were seen in the Mackenzie Zone during August through September with a single record from early October. Figure 1 and Table 2 both demonstrate a westward shift in the range of the bowhead population during the course of the season. As described below, the records in Amundsen Gulf probably reflect an eastward shift in hunting effort during the 1900's rather than a change in whale distribution.

A large reduction in the whale stock is indicated by the number of observations per year before and after 1900 (Bockstoe, 1980). During the seven cruises preceding 1900, there were 259 observations (37/cruise), whereas during the three cruises after 1900, there were only 24 observations (8/cruise). Also, all records from Amundsen Gulf were made after 1900. Thus, the prosecution of the hunt appears to have been carried farther east late in the whaling

Table 2.—Area, time period, and number of bowhead whale observations made from whaling ships, 1891-1906.

Area	Time period								Totals
	16-30 June	1-15 July	16-31 July	1-15 Aug.	16-31 Aug.	1-15 Sept.	16-30 Sept.	1-15 Oct.	
Amundsen Gulf	—	—	—	12	5	—	—	—	17
Bathurst Zone	2	13	26	86	47	16	—	—	190
Mackenzie Zone	—	—	—	6	24	28	17	1	76
Totals	2	13	26	104	76	44	17	1	283

era, after this stock of bowheads had been greatly reduced.

Recent Observations (1974-78)

Bowhead whales have been seen regularly in and north of Kugmallit Bay from 1976 to 1978 by personnel on boats and by aerial surveyors (Fig. 2). Boat activities began by about mid-July in all years and aerial surveys began by 1 July. The first observations in this region were on 3 August in 1976 and on 26 July in both 1977 and 1978. Aerial surveys continued to mid-August in each year, and boats continued to operate offshore until late October in 1976 and 1977 and to the end of September in 1978. The last dates on which whales were observed were 16 September in 1976, 17 September in 1977, and 14 September in 1978. Because there was a good potential to make observations before and after the time span during which whales were seen, the first and last dates of observations probably define fairly accurately the period during which bowheads were in this area.

The directions of movement of bowheads in the Mackenzie estuary region differed between the periods 26 July-31 August and 1-17 September (Fig. 3). Because of the small number of observations ($N=38$) and the low numbers observed travelling in certain directions, the observations from each of these periods were categorized as having either an easterly or westerly component, and a 2×2 contingency table was constructed. There was a statistically significant difference in directions of movement between the early and late time periods (Yates' corrected $\chi^2 = 4.83$, $df = 1$, $P < 0.05$).

The directions of movement also ap-

pear to differ from a uniform distribution within each time period, but there are too few observations for a meaningful statistical analysis. From 26 July to 31 August, more whales were oriented N-ENE than in any other direction; but in September, most were oriented W-NNW (Fig. 3).

There has been a relatively large number of recent observations of bowheads along the Yukon coast between Shingle Point and Kay Point during August and September (Fig. 4). Each of these sightings was of one to seven individuals. Most were within 3.2 km (2 miles) of the shore. On 13 September 1976, a minimum of 33 was observed in the area between Shingle Point and Kay Point.¹

Don McWatt,² on about 31 August 1975, observed four bowheads as he walked along the beach from Sabine Point to Shingle Point. They were swimming southeastward along the coast at the rate of a man walking. The whales were observed for about an hour, during which time they made several dives, each with an estimated duration of 10-15 minutes. McWatt suspected that these animals may have been feeding.

Not shown on Figure 4 are observations made by Mr. and Mrs. George Allen³ who regularly camp at Shingle Point and travel along the Yukon coast from early July to about mid-September. They say that bowheads

¹William Koski, Biologist, LGL Limited, Edmonton, Alberta, T5N 1P6, pers. commun., 14 September 1976.

²Don McWatt, resident, Aklavik, N.W.T. X0E 0A0, pers. commun., July 1976.

³Mr. and Mrs. George Allen, residents, Aklavik, N.W.T. X0E 0A0, pers. commun., July 1976.

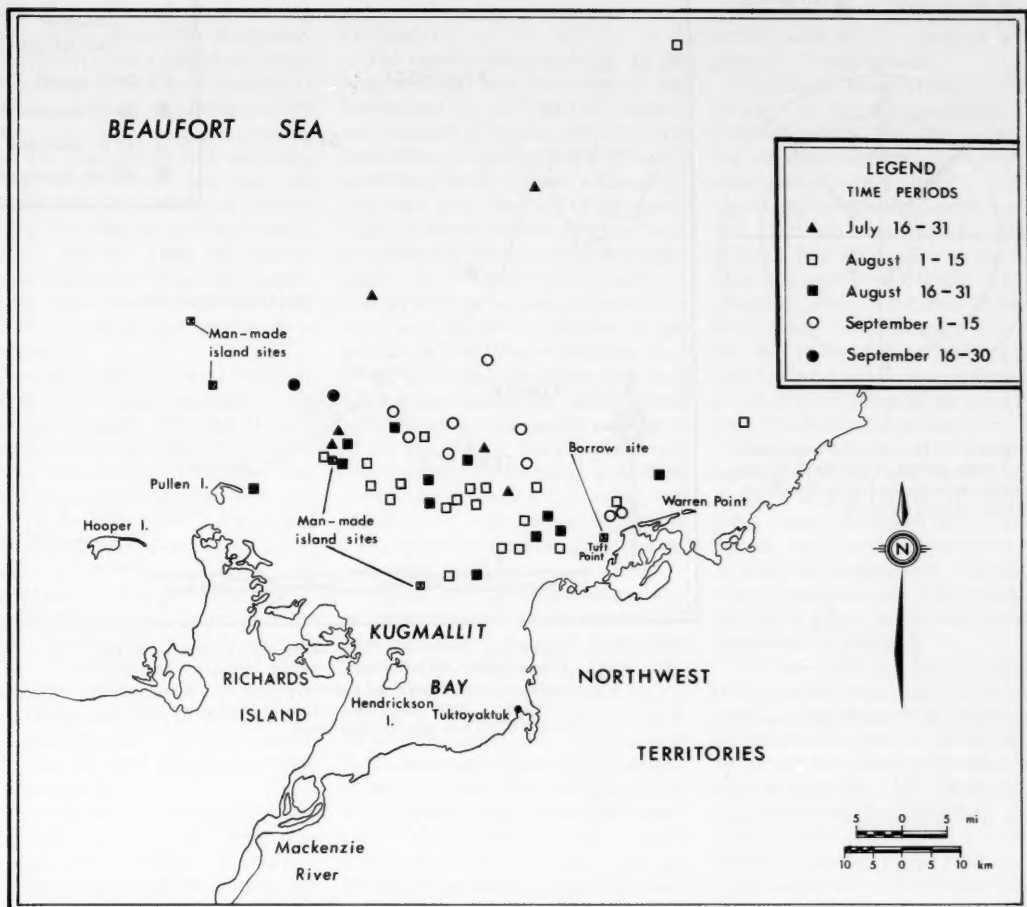


Figure 2. — Bowhead whale observations in the Mackenzie River estuary region of the Beaufort Sea, 1976-78. Each symbol represents an observation of one or more whales.

usually appear in this area in late August or early September. Commonly the bowheads approach to within a few meters of the beach.

Discussion

The whalers made the majority (67 percent) of their sightings and captures in the Bathurst Zone, particularly near Cape Bathurst (Fig. 1). The lesser importance to them of the Mackenzie Zone is particularly significant because

most cruises began from Herschel Island (Table 1), and the vessels hunted while passing through this area en route to the Cape Bathurst "whaling ground" (Cook, 1926). It was not until after mid-August that many whales were recorded from the Mackenzie Zone (Table 2). The failure of the whalers to find whales west of the Cape Bathurst area until after July adds support to the theory that this stock undertakes its eastward spring migration relatively far

offshore, rather than along the coast (Fraker et al., 1978; Fraker, 1979; Braham et al., 1980; Braham and Krogman⁴).

⁴Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

26 JULY - 31 AUGUST

1-17 SEPTEMBER

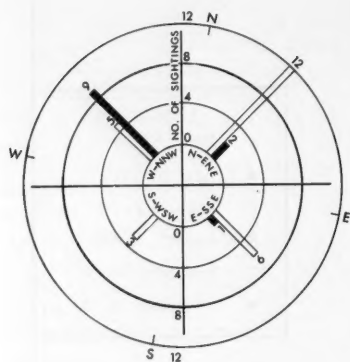


Figure 3.—Direction of movement and time period of bowhead whale observations in the Mackenzie River estuary region, 1976-78.

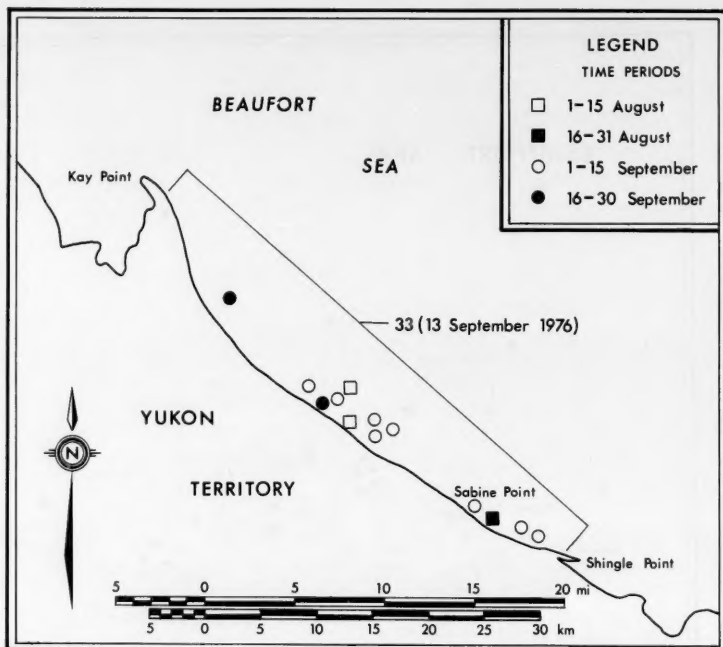


Figure 4.—Recent bowhead whale observations along the Yukon coast, 1973-76. Each symbol represents an observation of one or more individuals, except for a minimum of 33 whales which were observed on 13 September 1976 between Kay Point and Shingle Point.

The observations from Amundsen Gulf were all made after the turn of the century (Fig. 1). Until that time, the whalers had concentrated their attention on the productive whaling ground near Cape Bathurst and westward to near Herschel Island. But as the number of whales in the stock was reduced, the whalers extended their searches eastward. Cook (1926) also hunted farther eastward during this period, but not before, and he reported several sightings near Nelson Head in August of 1903 and 1905. Cook's sightings have been plotted by Fraker et al. (1978).

During the 1900's, more observations (17) were made in Amundsen Gulf than in the formerly productive areas of the Bathurst Zone (7) (Fig. 1). Thus it is possible that at least certain parts of

Amundsen Gulf (e.g., near Cape Parry, Nelson Head, and Cape Lyon) may have been proportionately (according to size) as important as the heavily used parts of the Bathurst Zone. Sightings from Amundsen Gulf did not appear in the 1890's data, apparently because the whalers did not need to travel that far east to catch whales. This assumes, as seems likely to us, that animals of the western Arctic stock used the entire summer range, and there were no substocks restricted to limited areas. The currently available data are insufficient to define well the distribution within Amundsen Gulf or to estimate the relative importance of various parts of this area compared with the Bathurst Zone.

If the Amundsen Gulf area is underrepresented in our sample, the

Bathurst Zone and, to a lesser extent, the Mackenzie Zone are overrepresented. This kind of bias is common in fishery-type data because of the tendency for fishermen (and whalers) to locate particularly productive areas which they continue to exploit: Tradition and uncertainty inhibit them from switching to other areas. Bodfish, on the other hand, frequently sought new whaling grounds, extending his searches beyond those of most of his contemporaries; because six of his logbooks provided data for this study, the degree of bias in Figure 1 and Table 2 is reduced.

In the Bathurst Zone, bowheads were observed out to a depth of about 50 m (164 feet) (Fig. 1). It was on this "20-25 fathom ground" that Bodfish was par-

ticularly successful in pursuing bowheads (Bodfish, 1936; Bockstoce, 1977). Bodfish was a careful and observant individual who not only searched a wide area, but also was comparatively systematic in recording his observations. For example, he took soundings of depths where whales were taken, and the observations which are farthest north of the Tuktoyaktuk Peninsula on Figure 1 were his. Thus, his observations are particularly important in defining the probable extent of the outer boundary of the summering grounds in this area.

The data clearly indicate a westward shift of the bowhead population as the open-water season proceeded (Fig. 1, Table 1). Within the Bathurst Zone, the earliest observations (late June and early July) were concentrated near Cape Bathurst, but later records (August and early September) indicate observations tended to be farther west. Although the vessels which had overwintered at Herschel Island at the beginning of the season operated first in the Mackenzie Zone, no whales were sighted there until early August, and most were observed in the latter half of August and in September (Table 2). The latest record, from near Herschel Island, was made on 2 October 1891.

The relatively few whalers' records from Amundsen Gulf were made only in August (Fig. 1, Table 2). Recent records show that some bowheads are present in the eastern Beaufort Sea and Amundsen Gulf by mid-May (Fraker et al., 1978; Fraker, 1979). Thus, the lateness of the whalers' first observations was a consequence of their inability (owing to ice conditions) to reach this area early in the season, and the earliest dates do not reflect the time of arrival of the first whales in this region.

Observations during 1976-78 suggest that the present pattern of bowheads in the eastern Beaufort Sea is similar to that recorded three-quarters of a century ago. Many of the recent sightings were made from vessels operating between Tuft Point, a source of granular fill material, and the sites of man-made islands (Fig. 2); the locations and dates of these observations are similar to what would be expected from running a

transect across the distribution shown in Figure 1.

The earliest recent sightings in the Kugmallit Bay area have come in the last week of July (1977 and 1978) and in the first week of August (1976); the earliest whalers' sightings in this area were in the latter half of August, with a single exception in the first half of the month (Fig. 1). We doubt that there has been any change in the basic pattern of utilization of this area by bowheads. It seems likely that the western part of the study area was poorly searched by the whalers in early August because they were expending most of their effort near Cape Bathurst and in the "20-25 fathom ground" which was highly productive at this time (Fig. 1, Table 2). The latest observations by the whalers in this area were in the first half of September, and this fits well with the mid-September dates when the latest recent observations were made.

Directions of movement differed significantly between the 26 July-31 August period and the 1-17 September period in 1976-78 (Fig. 3). During the earlier period, animals moved in all quadrants, but particularly those with an easterly component. Why such a large proportion should head eastward at this time is not clear. In September, 9 of 12 sightings were of bowheads moving W-NNW. Whales moving in these directions would eventually leave the Beaufort Sea, and we suspect that such movements are part of the fall migration.

The data available on direction of movement may not be representative because of the relatively small number of observations or because of movements which were too far offshore to be recorded. However, the strong tendency of September movements to be W-NNW suggests that these were migrational movements.

Bowheads apparently spend little time in the Beaufort Sea north of Alaska. The whalers passed through this area regularly en route to the eastern Beaufort Sea, but they rarely encountered whales there. As whalers left the whaling grounds late in the season they sometimes saw whales. These whales were apparently making a pas-

sage westward at this time, and logbook entries such as "... whales going quick ..." were typical.

The eastern Beaufort Sea region is clearly of major significance to bowhead whales, but the reasons for this are unknown. We believe that the most reasonable hypothesis is that the region constitutes an important feeding area. The occurrence of long migrations to summer feeding grounds is common among the great whales (Dawbin, 1966; Rice and Wolman, 1971; Small, 1971; Matthews, 1978). One way to assess this conjecture is to examine the relationship between bowhead distribution, as shown in Figure 1, and biological productivity.

In examining the relationship between productivity and distribution of Antarctic whales, Gulland (1974) compared whale abundance (from harvest records) with primary productivity and zooplankton standing crop. He found a closer correspondence with zooplankton standing crop, presumably because whales eat zooplankton.

Between 1971 and 1975, Grainger (1975) studied zooplankton abundance in the southern Beaufort Sea from about the Alaska-Yukon border to the eastern tip of the Tuktoyaktuk Peninsula and north to about lat. 71°N. He found the highest zooplankton standing crops north of the Tuktoyaktuk Peninsula within the area that Figure 1 indicates is highly important to bowheads. Unfortunately, neither the area near Cape Bathurst nor Amundsen Gulf, both of which may be of particular importance to the bowheads, has been studied.

Along the Yukon coast, where several recent observations of bowheads have been recorded, there are few data on zooplankton abundance. However, in the nearshore areas from Herschel Island to Shingle Point, Hsiao et al. (1977) found levels of primary productivity 4 to 10 times higher than elsewhere in the southern Beaufort Sea, and such an abundance may support a prolific growth of zooplankton upon which bowhead whales depend.

In discussing the major factors limiting primary production in the southeastern Beaufort Sea, Grainger (1975) identified the attenuation of light by

turbidity in the Mackenzie River plume as well as a lack of nitrate in waters outside the plume. The Mackenzie contributes a relatively large amount of nitrate to the Beaufort Sea system, but this is quickly consumed by plankton when the turbidity diminishes to the point that the water becomes euphotic. Although the overall circulation of water offshore in the Beaufort Sea is clockwise, there is generally north-eastward coastal movement of water in the southeastern Beaufort Sea toward the Amundsen Gulf owing to the Coriolis force (Herlinveaux and de Lange Boom, 1975). Mackenzie River water tends to flow northward as it discharges into the Beaufort Sea, but it is drawn northeastward into the general coastal movement so that it flows parallel to the Tuktoyaktuk Peninsula toward Amundsen Gulf. The farther the water gets from the river mouth, the lower the turbidity, the greater the penetration of light, and the greater the primary productivity—until the nitrates are depleted. The volume of water discharged from the Mackenzie is greatest in late June to mid-July, and turbidity is also highest at this time (Fraker et al., 1979). Thus the Mackenzie River turbidity plume affects the largest area early in the open-water period. As river flows diminish during the summer, the turbidity of the water decreases and the zone of highest productivity probably retreats toward the Mackenzie delta area. This hypothetical shift in the area of highest productivity would correspond to the gradual westward shift of the bowhead whale population which is seen in both the early whalers' records and the recent observations. A time lag in the growth of zooplankton populations in response to increased primary productivity would, of course, be expected. Therefore, we would not predict an exact correspondence between primary production and whale distribution.

Conclusions

The whaling records clearly indicated that the Bathurst Zone seaward to about the 50-m contour is of major importance to the bowhead whales as a summering ground (Fig. 1). The role of Amundsen Gulf in the summer range is

less clear, but at least some parts of it (e.g., near Cape Parry, Cape Lyon, and Nelson Head) may also be significant. The summering area probably represents a very important feeding ground. This conjecture is supported by the existing data on zooplankton standing crop and primary productivity in the southeastern Beaufort Sea. However, data on productivity are greatly limited with respect to location and time of collection (annually and seasonally). Each season, the initial distribution of bowheads in the eastern Beaufort Sea region is in Amundsen Gulf and the adjacent waters near Cape Bathurst. Over the open-water period, there is a gradual westward shift in the animals' range, which may be related to a shift in the area of high productivity. Recent observations in the Mackenzie Delta region indicates that the pattern of use of this area by bowheads has not changed since the whaling era three-quarters of a century ago.

Because the data on whale distribution and on primary and secondary productivity are limited in several respects, we believe that our conclusions should be taken as hypotheses. These hypotheses require testing by systematic studies of whale distribution as well as biological productivity and by a more comprehensive analysis of the whaling records. The latter approach is currently being pursued by Bockstoce.

Acknowledgments

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Spitsbergen Bowhead Stock: A Short Review

RANDALL R. REEVES

Introduction

The bowhead whale, *Balaena mysticetus*, had a nearly circumpolar distribution, historically, in the higher latitudes of the Northern Hemisphere. Five geographically separate stocks are recognized by the International Whaling Commission (IWC, 1978), primarily on the basis of arguments presented at its 1977 annual meeting in an unpublished report¹. These stocks are: 1) The Spitsbergen stock, estimated at 25,000 in 1679; 2) the Davis Strait stock, estimated at 6,000 before commercial exploitation; 3) the Hudson Bay stock, estimated at 700 prior to commercial hunting; 4) the Bering Sea stock, estimated at 18,000 in 1850; and 5) the Sea of Okhotsk stock, estimated at 6,500 before commercial exploitation (all from IWC, 1978).

The purpose of this paper is to summarize briefly the history of exploitation, the historical distribution, and the current status of the Spitsbergen stock. It is based on a review of literature.

Aboriginal Exploitation

This, the largest bowhead whale population, was the first to be exposed to European commercial hunting. The extent to which the Spitsbergen stock was hunted by aboriginal peoples is difficult to determine. Vibe's (1967) account of the development and movement of Eskimo cultures in Greenland, from which the following discussion is derived, indicates that the first immigration to north Greenland occurred in approximately 2500-2000 B.C. Both the Independence people, who were musk-ox hunters, and the Sarqaq people, who

were reindeer hunters, inhabited north Greenland off and on until about 500 B.C. The Dorset people, reindeer hunters, came about 100 B.C. and disappeared around 500 A.D. I know of no evidence that any of these people hunted whales, and almost certainly they did not hunt them off northeastern Greenland, where animals from the Spitsbergen stock would have been involved.

The Whaling (or Thule) Culture was established in northwestern Greenland between 900 and 1200 A.D. Some of these people immigrated to northeastern Greenland at least as early as 1480, when a skin boat carrying Eskimo whale hunters arrived from the northwest at Pearyland (Knuth, 1967). Whalebone and baleen lashings were recovered in an archaeological site at Pearyland, and the latter were radiocarbon dated as 470 ± 100 years old. Perhaps it was in the 15th century, then, that the Spitsbergen stock of bowheads first experienced the sting of primitive whaling weapons off northeastern Greenland. In the 15th and 16th centuries the Angmagssalik Eskimos (Inugsuk) of southeastern Greenland probably pushed northward, eventually meeting and merging with the Thule people to create what Vibe called the "Northeast Greenland Mixed Culture," which seems to have depended heavily on reindeer. That this culture exploited bowhead whales is suggested by the discovery of whale bones in a midden searched by Scoresby (1823) and another examined by Vibe (1967).

European whalers in the Greenland Sea reported several instances in which captured whales had stone harpoon heads or lance tips imbedded in their carcasses (Gray, 1935). Unaware of the

existence of Eskimos in northeastern Greenland, they interpreted such finds as evidence that bowheads immigrated into this area from Davis Strait or the Chukchi Sea. However, subsequent archaeological discoveries have demonstrated beyond reasonable doubt that these implements were fashioned and wielded by local Eskimos. Gray suggested that the decline and eventual extinction of this Stone Age civilization after 1823 may have been due, at least in part, to the drastic reduction in the bowhead whale population caused by commercial whaling. By 1870 the Northeast Greenland Mixed Culture appears to have vanished utterly (Gray, 1935), and the modern, rejuvenated settlement at Scoresbysund was not established until 1925 (Vibe, 1967).

Available information is too sparse to judge whether the early aboriginal inhabitants of northeastern Greenland had a significant impact on the Spitsbergen bowhead stock. However, the marginal nature of subsistence life in this unforgiving land suggests that Eskimo habitation was sporadic, and what whaling that did occur was probably local in impact and primitive in methodology. Eskimo residents of Scoresbysund are not known ever to have taken up the pursuit of large whales, although they do kill narwhals, *Monodon monoceros*, and white whales, *Delphinapterus leucas*, occasionally (Kapel, 1977), and they rely heavily on seals for subsistence (Kapel, 1975).

Tomilin (1957) referred to whale hunting along the Murman coast of Russia as early as the 9th century, but did not indicate, except by inference, that bowheads were among the exploited species. He did assert, with unfortunately little documentation, that hunters from the northern coasts of Russia sailed to Spitsbergen long before the island's "discovery" by Barents in 1596, to hunt whales, presumably including bowheads, and pinnipeds.

Commercial Exploitation, Whale Distribution, and Stock Identity

The history of the intensive European fishery that flourished around Spitsbergen and off east Greenland between 1610 and 1910 has been reviewed by

¹Mitchell, E. D. 1977. Initial population size of bowhead whale (*Balaena mysticetus*) stocks: cumulative catch estimates. Unpubl. manuscript submitted to IWC Scientific Committee, Canberra, Australia, June 1977, as SC/29/Doc. 33.

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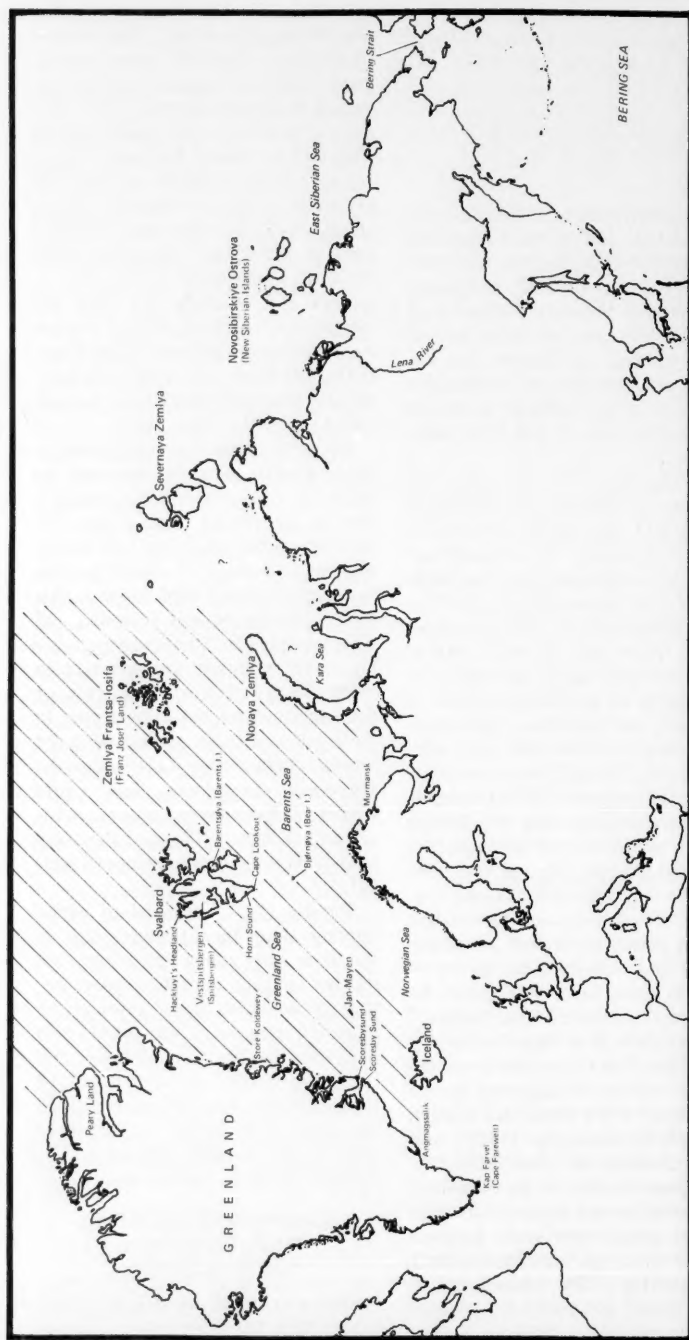


Figure 1. — Approximate historical range (hatched) of the Spitsbergen stock of bowhead whales, with place names mentioned in text.

many authors (e.g., Scoresby, 1820; Eschricht and Reinhardt, 1866; Southwell, 1898; Jenkins, 1921; Lubbock, 1937; Tomlin, 1957; and Jong, 1978). Though tens of thousands of whales were captured in those areas during this period, major questions about the Spitsbergen stock remain unresolved.

For instance, Scoresby (1820) observed that identifiable substocks, what he called "tribes," of whales occupied different grounds in summer and migrated southward in the fall by different routes. He mentioned differences in head shape and body proportions that, by his estimation, could have taxonomic significance. Eschricht and Reinhardt (1866) managed to attribute most of the differences pointed out by Scoresby to age and sex segregation within the whale population, but they were less able to dismiss the observations of Zorgdrager, "a Dutchman of great experience." Zorgdrager (1720) suggested that "west-ice whales," those killed between Spitsbergen and Greenland, were different from "south-ice whales," those killed south of Spitsbergen. "South-ice whales" had thinner, softer, yellow blubber; they appeared to come from the east and return to the east during the exceptional years when they appeared at all near Spitsbergen; and they were relatively naive and approachable compared with "west-ice whales." Eschricht and Reinhardt (1866) allowed that these characteristics could constitute evidence of geographic, but not necessarily systematic, separation. But Zorgdrager also had claimed that "south-ice whales" had a "more even" back than "west-ice whales," and this they found more difficult to reconcile with the single-species concept. The problem of variability within what is now called the Spitsbergen stock is beyond resolution; it is also beside the point as long as the population remains near extinction. There may be interesting parallels between this and the "ingutuk" problem in northern Alaska (Braham et al., 1980).

There are different opinions about how far eastward bowheads from the Spitsbergen stock wander(ed) (Fig. 1). Eschricht and Reinhardt (1866) were

doubtful of the species' occurrence as far east as Novaya Zemlya, and Ruud (1937) stated that bowheads are generally absent between Novaya Zemlya and Bering Strait. Tomilin (1957) evaluated these claims in light of old Russian literature and judged them to be in need of qualification. While some of his sources are not particularly convincing with respect to species identification, enough of them are offered to leave little doubt that bowheads occur(ed), at least sporadically, as far east as Novaya Zemlya and possibly even to the Kara Sea. Tomilin's argument was strengthened in May 1963 when a bowhead was sighted off Novaya Zemlya (at lat. 73°50'N, long. 49°20'E) by Norwegian small whale hunters (Jonsgård, 1964) and again, in May 1973, when an adult and calf were seen swimming northeastward at lat. 74°40'N, long. 52°20'E (Benjaminson et al., 1976). Given Zörgdrager's (1720) conviction (see above) that "south-ice whales" came to Spitsbergen from the east, it is reasonable to suppose there was (and may still be) either an eastern stock of bowheads in the Barents and Kara Seas or a part of the Spitsbergen stock which spent at least part of some years in these waters.

Another unanswered question is the winter whereabouts of Spitsbergen bowheads. Since virtually all hunting occurred in spring, summer, or fall, there are, to my knowledge, no published winter observations of bowheads between east Greenland and the East Siberian Sea. Southwell (1898), without giving evidence, stated that bowheads winter east of Greenland at about lat. 65°N; Gray (1931) referred to "their supposed winter quarters, between Iceland and Cape Farewell." Eschricht and Reinhardt (1866) claimed "we know that it [the bowhead] sometimes repairs to the north coast of Iceland" but gave no supporting evidence. Saemundsson (1939) asserted that "no records as to its occurrence in Icelandic waters are at hand," though he admitted that in exceptional ice-years the bowhead probably did come close to the island's northwest coast. Scoresby (1820) knew of "some rare instances" of large whales being seen early in the

season along the ice edge extending from Point Lookout (Spitsbergen) to Bear Island, which suggests wintering in the Norwegian or Barents Sea. Gray (1931) noted that there is open water "north of Siberia" in winter, and implied that some bowheads, in some years at least, overwinter(ed) there.

The best that can be said is that the population probably remains close to the southern boundary of winter ice and moves northward as the ice cover recedes and disintegrates in spring. Robert Gray (1889), an experienced whaler, explained: "...the area inhabited by the *Mysticetus* might be represented by a band of variable breadth running parallel to the edge of the ice, the animal being most usually present where the temperature of the water is just above the freezing point."

The bowhead's distribution in northeast Atlantic waters from spring through autumn is relatively well mapped. In 1634 Dutch sailors wintering on Jan Mayen first noticed bowheads passing the island on 27 March, and whales were seen daily "in larger or smaller numbers" until the end of April (Southwell, 1898). Saemundsson (1939) reported a sighting at the ice edge 40 miles off the northwest coast of Iceland in spring 1879. According to Southwell, the whales were next seen off western Spitsbergen in mid-May, being found north and west of there throughout the summer.

Gray (1936) summarized Scoresby's reflections on the principal whaling grounds and seasons. In April whales were caught in open water, outside the ice, within view of Hackluyt's Headland at about lat. 80°N. (According to Gray (1931), some autumn whaling took place there, too.) By the end of April this episode would end, as the whales, many accompanied by calves, dispersed into the ice. Hunting resumed in May and lasted through June or July between lat. 78° and 80°N, when whales were found "among the ice; in bays or 'bights' in its margin; among the broken or 'pack' ice; among the unbroken ice or 'floes' and often between the two kinds of ice." During May, Spitsbergen was often in sight from where the whales were caught.

Scoresby (1823) noted that before 1814 most whaling was done between lat. 76° and 80°N and at lat. 79°N within "thirty or forty leagues" of Spitsbergen. After 1814, however, the hunting was so poor in these areas that new grounds had to be found. Scoresby and others began thereafter to work the ice between lat. 71° and 74°N, close to the Greenland coast. Southwell (1898) described what he called the "south fishing ground" as between lat. 72° and 75°N at about long. 13°W, off east Greenland, and it was "fished" mainly between mid-June and early August. Apparently it was this "south fishing ground" that Vibe (1967) had in mind when he asserted: "The main summer feeding ground of the Greenland Whale off Northeast Greenland seems to be the continental slope between 200 and 1000 m."

An additional whaling ground was called the "'southward' fishing station" (Scoresby quoted by Gray, 1936). It was in open water or "bay ice" to the south of Spitsbergen at about lat. 76°N (with Horn Sound and Cape Lookout sometimes in sight). This may be where Zörgdrager's "south-ice whales" were found.

Gray (1936), like Eschricht and Reinhardt (1866), dismissed Scoresby's concerns about variability among bowheads by concluding that "differences between the whales caught at the different fishings seem to have been merely a matter of age and sex." The whales caught in ice between lat. 78° and 80°N were presumably immature; those killed in April at lat. 80°N, "breeding females"; those taken at lat. 76°N from April to July, adult males; and those found in summer ice off east Greenland, mostly males.

Historical Status

There is little point in recounting details of the Spitsbergen stock's decline to commercial extinction. The average number of whales taken per voyage by each Peterhead vessel was 16.8 in the period 1800-09; it declined steadily thereafter to 1.7 between 1850 and 1859 (Gray, 1929). The total fleet caught 85 whales in the Greenland Sea in the period 1880-89, but only 38 between

1890 and 1899 and 28 in 1900-09. Gray (1929) reflected: "... in the 'eighties we seldom saw more than one or two at a time and seldom more than a dozen or two in a voyage. In 1890 only six were seen by all the ships, and in 1898 not a single one." The continued pursuit of bowheads east of Greenland in these waning years of the fishery was "subsidized" by the walrus, polar bears, harp and hooded seals, bottlenose whales, narwhals, and musk oxen that could, if nothing more, at least cut the losses of an unsuccessful voyage (see Lubbock, 1937).

Reasons for Decline and Failure to Recover

For more than half a century now the Spitsbergen stock has enjoyed virtually complete immunity from hunting. Only four animals are known to have been taken since 1911, and those were killed by Norwegians in 1932 (Table 1). If the population were still viable at the turn of the century, there is reason to think some recovery in numbers would have been achieved. However, there is no evidence whatsoever to suggest that the population has increased. There is, on the contrary, reason to fear that the Spitsbergen stock was below a critical level when its exploitation ceased and that it has either stabilized at a relic number or is in the process of declining to extinction.

There are several lines of argument to account for the Spitsbergen stock's apparently drastic decline. Some are less plausible than others. James Lamont (1861), a walrus hunting yachtsman, observed that by the middle of the 19th century the whales had "entirely deserted" the vicinity of Spitsbergen. He believed the "principal reason to be that the seas around Spitsbergen have become *too shallow* for them." Vibe (1967) constructed a different ecological explanation, to wit, that "special conditions of currents, drift-ice, and production in the Arctic seas were the deciding factors in its [the bowhead's] mass occurrence in different places at different times." He assumed that instability of the whale's habitat made its survival tenuous enough without whaling and that whaling simply hastened an

Table 1.—Twentieth century records of bowhead whales east of Cape Farewell.

Date	Number	Nature of evidence	Location	Source
1900-09	28	Killed	Off east Greenland	Gray, 1929
1910	5	Killed	Between lat. 78°N, long. 1°W and lat. 79°N, long. 1°E.	Lubbock, 1937:450
1911	1	Killed	Svalbard	Jongsgård, 1977:424
1917	1	Sighted	In ice off east Greenland between lat. 64° and 65°N	Ruud, 1937
Summer 1932	4	Killed	At the ice edge north of Spitsbergen	Ruud, 1937; and see Jongsgård, 1964
1940	1	Sighted	Mouth of Scoresby Sound, east Greenland	Vibe, 1967
August 1953	2	Sighted	In drift ice at lat. 76°N 40 mi. east of Store Koldewey, east Greenland	Vibe, 1967
August 20, 1958	1	Sighted	Off northwest Spitsbergen at lat. 79°48'N, long. 10°07'E	Christiansen, 1962
May 23, 1963	1	Sighted	West of Novaya Zemlya at lat. 73°50'N, long. 49°20'E	Jongsgård, 1964
June 1964	1	Sighted	Mouth of Scoresby Sound, east Greenland	Vibe, 1967
May 29, 1973	2 (adult & young)	Sighted	West of Novaya Zemlya at lat. 74°40'N, long. 52°20'E	Benjaminson et al., 1976
August 1974	1	Stranded parts recovered	Mistakodden at the east side of Spitsbergen	Larsen, 1976
April 23, 1979	2	Sighted	Off northeast Greenland at lat. 80°45'N, long. 05°33'E	Anonymous, in press
Aug. 2, 1979	2	Sighted (identification unconfirmed)	Off SE Greenland at approx. lat 61°05'N, long. 42°10'W	Jongsgård, 1980 ¹
May 21 and 25, 1980	1	Sighted	Off Finnmark, North Norway, at approx. lat. 71°00'N, long. 28°51'E	Jongsgård, 1980 ¹

¹See text footnote 2.

ebbing cycle for the species in the eastern North Atlantic.

Sergeant (1978) suggested that recovery of bowheads in Canada's eastern Arctic could be retarded by killer whale, *Orcinus orca*, predation. Since killer whales are common enough in the subarctic eastern North Atlantic to have been themselves the object of commercial exploitation in the 20th century (Jongsgård and Lyshoel, 1970), their role in preventing the Spitsbergen stock's recovery cannot be entirely discounted.

Gray (1889) suggested that competition for food between bowheads and blue whales, *Balaenoptera musculus*, (and possibly in this case including other balaenopterids) was an important factor in preventing the former's recovery. As he put it, "... the struggle all along has been one of a slow swimmer with long whalebone plates *versus* a swift and active animal with short plates, with this qualification, however, that *Mysticetus* has become specialized to inhabit those parts of the feeding-grounds covered by ice, its congener [sic] to occupy rather the open ocean. The prolonged prosecution of the

Whale fishery, and the consequent reduction in numbers of the Greenland Whale, has favoured a corresponding increase in the abundance of the Blue Whale, at the same time permitting its intrusion upon the habitat of *Mysticetus*, and hence its frequent appearance amongst the ice, where for weeks the ships now search vainly for the Greenland Right Whale." Since blue whales were themselves heavily exploited in the eastern North Atlantic after 1890 (Jongsgård, 1977), the bowhead should have had a timely opportunity to regain its niche. Sergeant (1978) considered Gray's competition "hypothesis" and found it difficult to accept, "unless the ice-covered area was so poor in plankton that the bowhead had to move out to the edges, and then, surely competition would always have occurred and the niches become well defined."

However susceptible to ecological instabilities, predation, or interspecies competition the bowhead may be, its demise was most likely a direct result of overhunting. The whalers spared neither males nor females, young nor old. Gray (1929) referred to the "waste-

ful method of carrying on the fishing" that involved the frequent capture of very young whales. This practice became common in the late 18th century and continued to the end of the fishery. Southwell (1898) observed that "Females accompanied by suckers are now rarely met with, and it follows that they must either have a secure hiding-place . . . or that reproduction has for many years been greatly arrested, or has almost ceased."

Present Status

Published 20th century records of bowheads in the Spitsbergen stock area are listed in Table 1. As Jonsgård (1964) inferred, the paucity of bowhead sightings in the present century cannot be attributed solely to a lack of observer effort. Norwegian small whale hunters (looking for minke, *Balaenoptera acutorostrata*; bottlenose, *Hyperodon ampullatus*; pilot, *Globocephala malaena*; and killer whales) have been working in the vicinity of Spitsbergen since at least 1949 (see Jonsgård, 1977). Some of these vessels have carried observers from the Institute of Marine Research (Bergen), whose presence on board probably improves the chance of a sighting's being noted and reported.

I have not attempted to correlate small whale hunting vessel cruise tracks and schedules with those of the earlier bowhead whaling vessels. Reports by Christensen (1972, 1974) and Benjaminsen et al. (1976) gave details of Norwegian small whale research cruises during recent years near Spitsbergen and east Greenland. It may be possible to plot and compare Norwegian searching effort with historically profitable bowhead whaling areas (by season) in order to document changes in whale abundance or distribution. If modern Norwegian small whale hunters have in fact been searching (in appropriate seasons) areas where bowheads once were common, then the lack of more incidental sightings takes on greater meaning. However, if their timing or routes have been out of phase with those of the early bowhead whalers, then it is possible that more whales survive than is generally assumed.

Jonsgård² is not sanguine about the existence of a viable stock in the Spitsbergen-Barents Sea area. He suggests that the few whales seen there since World War II may be strays from other stocks.

In any case, the IWC Scientific Committee's conclusion—that "the stock is now at a very low level" (IWC, 1978)—seems a fair assessment until new information becomes available to argue otherwise.

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Ingutuk: A Morphological Variant of the Bowhead Whale, *Balaena mysticetus*

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Introduction

Eighteenth and nineteenth century commercial whalers working in Northern Hemisphere waters pursued and nearly exterminated all species of whales belonging to the family Balaenidae, collectively known as "right whales." In describing the right whales that they hunted, the whalers recognized at least five types. The two most notable were the Pacific and Atlantic right whale, *Balaena* (= *Eubalaena*) *glacialis*, and the Greenland right or bowhead whale, *Balaena mysticetus*. The three others were referred to as the "great polar whale," the "arctic ice whale," and Roys' "bunchback" (Scammon, 1874), all three of which looked like and were taken with bowhead whales.

During the annual hunt of bowhead whales in Alaska, Eskimo whalers recognize a whale which looks somewhat different from most bowheads in the population. They call this animal ingutuk. On 3 May 1978, a bowhead whale taken at Barrow, Alaska, was identified by some Eskimos as an ingutuk. The taking of this whale exceeded by one the three-whale quota established for Barrow by agreement between the U.S. government and the Alaskan Eskimo Whaling Commission under a mandate from the International Whaling Commission (IWC). Eskimo

whalers argued that the harvest restriction imposed by the IWC applied only to bowheads and, therefore, an unlimited number of ingutuks could be taken. Some Eskimos contended that the ingutuk was a different species than the bowhead; some that it was *B. glacialis*; and others thought it was neither *B. mysticetus* nor *B. glacialis*.

This paper is a preliminary evaluation of historical information and recent biological data relevant to the question of whether the ingutuk is: 1) A distinct species, 2) *B. glacialis*, or 3) a morphological variant of *B. mysticetus*.

Historical Evidence

Taxonomic Considerations and Eskimo Nomenclature

Clear morphological distinctions have been established between *B. glacialis* and *B. mysticetus* (e.g., Eschricht and Reinhardt, 1866; True, 1904; Allen, 1908; Rice, 1977). For example, *B. glacialis* possess characteristic callosities on their heads; bowheads do not. Among people who are familiar with both species there is no confusion in identification. *Balaena glacialis* occurred in the summer near St. Lawrence Island until several decades ago (Tomlin, 1957; Omura et al., 1969). Eskimo whalers there clearly recognize the distinction between the two species.

The term "great polar whale" frequently occurred in the literature independent of references to Greenland right or bowhead whales. However, from the sketches and notes in Scoresby (1820), Cheever (1850), and Scammon (1874)—we have little doubt that the great polar whale and the bowhead were the same. Identities of the Arctic ice whale and the bunchback are less clear.

Both were taken with bowheads, though they were frequently described as smaller and occurring earlier in the spring than bowheads (Scoresby, 1820; Scammon, 1874). The Arctic ice whale was described by commercial whalers as a smaller bowhead-like whale, closely associated with the ice and more docile than the larger bowheads which were taken in open water. In contrast, some behavioral differences as well as the occurrence of a bulge or lump on the caudal peduncle were characteristic of the bunchback whale. Some of the characteristics ascribed to the Arctic ice whale and the bunchback, in part, also describe the ingutuk.

Classification of the ingutuk has perplexed Yankee and Eskimo whalers alike. Hadley (1915), Allen (cited in Bailey and Hendee, 1926), and Brower,¹ well-known commercial whalers in Alaska at the turn of the 20th century, believed that the ingutuk was a separate species from the bowhead. Stefansson (1944) reported that some Eskimos believed the ingutuk to be a separate species, whereas others considered it to be a yearling or 2-year-old bowhead. Scammon (1874) regarded differences in appearance among bowheads as age-related.

Confusion over the proper usage of Eskimo terms also may have added to the controversy. In the Eskimo spoken languages of Inupiaq and Yup'ik there are different names for each age, sex, or developmental stage of most animal species, including the bowhead. The Inupiaq word for bowhead is agvik, which means "the whale." The more commonly seen slender bowhead is called usingwachak by Inupiaq speakers in villages from Point Hope south. North and east of Point Hope variations of the term kairalik² (Rice, 1977) or kiyralik^{3,4} describe size categories of

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¹Brower, C. D. 1863-1939. The northernmost American. An autobiography. 895 p. (Condensed and published as: Brower, C. D. 1942. Fifty years below zero. Dodd, Mead and Co., N.Y., 310 p.)

²Arnold Brower, Sr., Barrow, AK 99723, pers. commun.

³Naval Arctic Research Laboratory, 1972. Eskimo whaling at Barrow, Alaska. Unpubl. manuscript, 24 p. Naval Arctic Research Laboratory, Barrow, AK 99723.

⁴Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus*) in the western Arctic. Unpubl. manuscript, 99 p. Dep. Biol., Univ. South. Calif., Los Angeles, CA 90007.

the apparent adult, long-slender (usingwachaek) bowhead. Kiyralik is a small bowhead; kiyrallivuk, a large male, and kiyrallivoak, an extra large male. Short, fat whales (about 8 m in length) with some features distinct from usingwachaek and kiyralik are called ingutuk. Both sexes are included in this term (see footnote 3), but it is generally associated with females, as larger females with apparent ingutuk features are called ingutuvuk ("one who carries calf").

Geographic Isolation

If ingutuks are not *B. glacialis*, perhaps their occurrence in the western Arctic bowhead population is a result of emigration from isolated bowhead populations in the Okhotsk Sea (U.S.S.R.) or the North Atlantic Ocean. Subspecific separation between the Okhotsk and western Arctic bowhead populations has been suggested by Berzin and Kuz'min (1975), though data to support this hypothesis, if available, were not presented. Plots of early Yankee bowhead harvest records (Townsend, 1935) suggest that these two populations were once one. This contention is supported by recent analysis of additional historical whaling records⁵. However, currently there are so few whales in the western Arctic and Okhotsk populations that continued intermixing is unlikely.

Emigration of ingutuks from the North Atlantic population(s) of bowheads by way of Canada appears plausible (from review of Figure 1 in Braham et al.⁶); however, the infrequency of sightings in northern Canada east of Amundsen Gulf suggests separation. Whaling gear (e.g., harpoon lances and bombs) from Atlantic whalers has been found in bowheads taken in the Bering Sea and U.S. Arctic Ocean

Table 1.—Bowhead whale characters used by Eskimos, early naturalists, and Yankee whalers to separate ingutuks from bowheads. "Positive characters" are those features believed to be common to ingutuks only; "shared characters" can be classified to noningutuk variants. Data were compiled from unpublished manuscripts of F. Durham¹ and D. Foote², interviews with Alaskan Eskimos, and accounts of early whalers (Scoresby, 1820; Eschricht and Reinhard, 1866; Scammon, 1874; Allen, 1908; and Bower³).

Positive characters	Shared characters	Insufficient evidence
Shorter baleen Thinner, lighter baleen Greater girth per length Meat more tender	Short body length Skin color greyish Secondary mandibular curve Baleen color greyish Straight baleen rows Rostrum flattened Gum tissue whiter Mouth more curved Padded loins Caudal hump Flippers shorter, wider, and less pointed Flukes smaller, smooth edges Docile Readily floats	Thicker, two layer blubber Denser bone Thicker skin Gum tissue extends farther down baleen

¹Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus*) in the western Arctic. Unpubl. manuscr., 99 p. Dep. Biol., Univ. South. Calif., Los Angeles, CA 90007.

²Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpubl. manuscr., 78 p. Geogr. Dep., McGill Univ., Montreal, Que., Can.

³Brower, C. D. 1863-1939. The northernmost American. An autobiography. 895 p. (Condensed and published as Brower, C. D. 1942. Fifty years below zero. Dodd, Mead and Co., N.Y., 310 p.)

(Eschricht and Reinhard, 1866; Scammon, 1874; Tomilin, 1957). One cannot rule out the possibility, however, that commercial whalers and Eskimos frequently traded or sold their hunting gear to other whalers and Eskimos across the circumpolar region.

Proportion of Ingutuks Observed

Estimates of ingutuks in the population are available from data of Foote⁷ and from Eskimo harvest data of 1973-79. Foote spent several years during the early 1960's studying bowhead whales at Point Hope, Alaska. The ingutuk problem was of particular interest to him. With the aid of several experienced Eskimo whalers, Foote attempted to determine what percentage of the population migrating past Point Hope consisted of ingutuks. In 1962 he classified 12 of 80 whales (15 percent) as ingutuk and 85 percent as usingwachaek. From 1973 to June 1979 Eskimo whalers at Point Hope and Barrow landed 112 bowheads, of which 14 (12.5 percent) were described by the whalers as ingutuks. The similarity of these two estimates suggests that the percentage of ingutuks in the population has not changed appreciably over the past 15 years.

⁷Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpubl. manuscr., 78 p. Geogr. Dep., McGill Univ., Montreal, Que., Can.

Biological Evidence

Morphological Features

Eskimos, Yankee whalers, and scientists have identified 22 morphological and behavioral features that describe the differences among whales in the bowhead population (Table 1). From reviewing these characters with experienced Eskimo whalers and interpreting the unpublished findings of Foote (footnote 7) and Durham (footnote 4), we found that 14 characters (61 percent) were not unique to the ingutuk. Four characters (18 percent) appear to be uniquely descriptive of ingutuk; the remaining four characters cannot be assigned clearly to either form.

These data do not exclude the possibility that the ingutuk represents one end of the normal distribution of characters. Occasional whales with a combination of characters usually attributed to ingutuk, usingwachaek, and kiyralik have been reported (footnote 4), suggesting that a range of features may occur within a given individual as well as within the population. While numerous contradictions exist, a suite of characters seems to exist that distinguishes ingutuks from other bowheads more often than would be expected from random association.

Sex and Size-Class Variation

Several Eskimos interviewed at Barrow in 1977 and 1978 stated that the

⁵John Bockstoe, Curator of Ethnology, New Bedford Whaling Museum, 18 Johnny Cake Hill, New Bedford, MA 02740, pers. commun.

⁶Braham, H., B. Krogman, and G. Carroll. 1979. Population biology of the bowhead whale (*Balaena mysticetus*) II: Migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution and life history of white whales (*Delphinapterus leucas*). Unpubl. final OCSEAP report, 118 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

Table 2.—Sex and size categorization of the reported ingutuk and ingutuvuk bowhead whales taken by Alaskan Eskimos, 1973-79. Data from Braham et al.¹, 1980; and Marquette², 1979.

Date killed	Size (cm)		Eskimo village where taken
	Males	Females	
23 May 1973 ³		855	Barrow
16 May 1974		41,135	Barrow
29 May 1974		724	Barrow
24 Apr 1975		4,5(1,097)	Point Hope
10 May 1975		846	Point Hope
13 May 1975 ⁴		927	Barrow
20 May 1975		784	Barrow
6 May 1976		825	Point Hope
17 May 1976		854	Barrow
10 Sep 1976		41,600	Barrow
2 May 1978 ⁵	838		Barrow
17 Apr 1979		853	Point Hope
16 May 1979	874		Barrow
26 May 1979	830		Barrow

¹Braham, H., B. Krogman, W. Marquette, D. Rugh, J. Johnson, M. Nerini, S. Leatherwood, M. Dahlheim, R. Sonntag, G. Carroll, T. Bray, S. Savage, and J. Cubbage. 1979. Bowhead whale (*Balaena mysticetus*) preliminary research results, June-December 1978. NWAFC Processed rep. 79-8, 40 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

²Marquette, W. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

³Only Barrow spring data.

⁴Reported to be an ingutuvuk.

⁵Sex not determined; thought to be a female.

⁶Extracted from Marquette (NMFS) field notes.

⁷Data from 1977 are incomplete. None of the 29 whales landed that year was identified as ingutuk. The whale taken 3 May 1978 at Barrow was incorrectly identified as ingutuk (Braham et al., 1979); it does not appear in this table.

term ingutuk refers to a short, fat female; none knew of the Eskimo name for a male ingutuk. According to Rainey (1947) some morphological and behavioral characteristics attributed to ingutuks also described young female bowheads.

Since 1973 National Marine Fisheries Service biologists have collected size and sex data on ingutuks at Point Hope and Barrow, Alaska (Marquette⁸; 1979). From April 1973 to June 1979, 14 harvested whales were identified by Eskimos as ingutuks. Of these, 10 were females, 1 was thought to be a female (but not verified), and 3 were males (Table 2). The males were taken during the 1978 and 1979 spring hunts

⁸Marquette, W. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-76, and a biological summary of the species. Processed rep., 79 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

Table 3.—Contingency tables of frequency distribution for comparison of total body length and sex ratio (where measurements and sex were appropriately determined) among ingutuk versus bowhead whales from the western Arctic population taken during the Alaskan Eskimo subsistence hunt at Point Hope and Barrow, Alaska, 1973-79.

	Among size comparison				Among sex ratio comparison			
	Frequency distribution				Frequency distribution			
	Greater than 1,000 cm		Less than 1,000 cm		Males		Females	
	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
Ingutuks	3	5.22	11	8.78	3	6.42	10	6.58
Bowheads ²	44	41.78	68	70.22	35	31.58	29	32.42
	$\Sigma\chi^2 = 1.70^{ns}$ (1 df)				$\Sigma\chi^2 = 4.32^*$ (1 df)			

ns = not significant.

* = significant at the 0.05 level (Yates correction).

¹The 1,097 cm whale taken at Point Hope on 24 April 1975 was not used in this analysis because its sex was not confirmed.

²Refers to all noningutuk type whales taken during the bowhead whale hunt.

(Braham et al., 1979; 1980). The mean length of males was 847.3 cm (standard deviation [SD] 23.4, $n = 3$); for females the mean length was 940.3 cm (SD 255.8, $n = 10$). Foote (footnote 7) observed only one male ingutuk taken during his study at Point Hope.

Because by inference the term ingutuk is related to ingutuvuk, we tested to see whether there was a disproportionate number of female ingutuks (including ingutuvuks) in the bowhead population. There were 3 male and 10 female ingutuks tested against 35 male and 29 female bowheads (total 64 bowheads sexed) (Table 3). A significant difference was found ($\chi^2: P < 0.05$) suggesting that the ingutuk phenotypic expression is predominantly a female related trait. We reject the alternate possibility that female ingutuks are selected during the hunt since the sex of a whale cannot be determined prior to a kill. Since no special term is used for male ingutuks, we must assume that the term ingutuk had or has no special gender or that it is actually a female term, as is ingutuvuk (footnote 3). In at least two instances NMFS biologists have received testes from two noningutuk whales sexed as females. Thus, the sex identification of ingutuks prior to 1978 is in question. The male-to-female sex ratio of all identified bowheads harvested since 1973 is approximately 1.13:1.00.

The fact that 3 of 14 ingutuk-type whales taken since 1973 were over

1,000 cm in length suggests that ingutuks grow to become ingutuvuks (Marquette, footnote 8 and 1979); we chose 1,000 cm as the length to test whether the ingutuk type was represented differently in the bowhead population according to size. There were 3 ingutuks less than 1,000 cm and 11 greater than 1,000 cm tested against 44 bowheads less than 1,000 cm and 63 greater than 1,000 cm. No difference in length was found for the two size categories between ingutuks (including ingutuvuks) and all other bowheads (Table 3).

Genetic-Biochemical Analysis

Since 1977, NMFS has been investigating the genetics and biochemistry of bowhead whales in an attempt to describe further the biology of this species. Four bowhead whales were karyotyped in 1978; each had a diploid chromosome count ($2n$) of 42 (Jarrell, 1979). An additional four have been karyotyped since 1978 with the same results. We examined the chromosomes of one ingutuk and found it to be similar to other bowheads. All other baleen whales tested have a chromosome count of 44 (Duffield, 1977). No chromosome samples have been collected from *B. glacialis* for comparison.

Electrophoretic analysis of liver tissues from nine bowheads (including one ingutuk) collected in 1977 and 1978 showed that 6 of the 30 enzyme systems (20 percent) tested exhibited variability

in at least one individual⁹. One whale accounted for much of this variability, differing from the others in 4 of 30 enzyme systems. However, this whale did not possess morphological characteristics attributed to ingutuk. Conversely, the ingutuk sampled was not distinguishable from the other bowheads by electrophoresis.

Electrophoretic analysis of blood proteins provided similar results¹⁰. Of three whales sampled in 1978, all had identical hemoglobins. One animal differed in one of five serum proteins; it was not the ingutuk specimen.

These findings, although based on few samples, suggest that protein variability is not correlated with observed morphological differences within the species. Electrophoretic data from marine mammals should, however, be viewed with caution (Sharp, In press).

Conclusions

It is indisputable that some bowhead whales differ in appearance, morphologically, although it often takes an experienced observer to make the distinction. The most apparent morphological variant is called ingutuk. However, the preponderant circumstantial and direct evidence suggests that a clear distinction between ingutuk and noningutuk bowheads cannot always be made.

The possibility that the ingutuk is a developmental stage which will grow to become an ingutuvuk, and presumably a "normal" bowhead, is suggested by the use of the word in some Eskimo villages as well as by size comparisons among harvested animals. The discrepancies noted in assigning "ingutuk" to the female gender may, in fact, be because ingutuk is a female sex-related trait, or perhaps simply because of inaccuracies in sexing animals.

Although morphometric and genetic-biochemical analyses of bowhead whales are not complete, we believe that the ingutuk is not a species

separate from the bowhead. This conclusion is supported by the most experienced Eskimo whaling captains we interviewed¹¹ (footnote 2). While future research will be aimed at further investigation of the explanations presented in this paper, it appears that the ingutuk is within the range of variation in the western Arctic population of bowhead whales.

Acknowledgments

We depended heavily on two previously unpublished manuscripts, one by Floyd Durham and one by Donald Foote, and on interviews with Alaskan Eskimo whaling captains, in particular Arnold Brower, Sr., and Kenny Toovak of Barrow; Jerry Wongittilin, Sr., of Savoonga; and Conrad Oozeva, Roger Silook, and Vernon Slwooko, of Gambell. Constructive criticism during various drafts of this paper was provided by Deborah Duffield, Portland State University, Portland, Oreg.; Dennis Hedgecock, Bodega Marine Laboratory, Bodega Bay, Calif.; Thomas Loughlin, Office of Marine Mammals and Endangered Species, NOAA, Washington, D.C.; Roger Pearson, NWAFC, Seattle, Wash.; William Perrin, Southwest Fisheries Center, NMFS, La Jolla, Calif.; Randall Reeves, U.S. National Museum, Washington, D.C.; Jeanette Thomas, Hubbs-Sea World Research Institute, San Diego, Calif., and Teresa Bray, Bruce Krogman, Willman Marquette, Mary Nerini, Dale Rice, and Michael Tillman, National Marine Mammal Laboratory, Seattle, Wash.

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⁹Analysis conducted by Dennis Hedgecock, Univ. Calif., Bodega Marine Laboratory, Bodega Bay, CA 94923.

¹⁰Analysis conducted by Deborah Duffield, Biol. Dep., Portland State Univ., Portland, OR 97207.

¹¹Vernon Slwooko and Conrad Oozeva, Gambell, AK 99742; Jerry Wongittilin, Sr., Savoonga, AK 99759, pers. commun.

External Morphology of Bowhead Fetuses and Calves

FLOYD E. DURHAM

Introduction

There have been few studies of early development and reproduction in the bowhead or Greenland right whale, *Balaena mysticetus*. Fetuses and young secured from the North Atlantic by early European whalers provided the basis for some information published by Eschricht and Reinhardt (1866) on the early development of bowheads; Home (1812) examined the ear from a neonatal bowhead obtained by Scoresby on his last voyage to the Arctic; Meek (1918) described for the first time the female reproductive system, based on a 35.5 cm (14-inch) fetus, while Gray (1929) wrote on the breeding habits. Marquette¹ summarized and listed additional references on studies of fetal, young, and mature bowheads.

Coastal Eskimos in northwestern Alaska take mostly young bowhead whales. As a result, fetal, newborn, or sexually mature animals are seldom observed. During the 13-year period 1961-73, I collected specimen materials and measurements from bowheads in Alaska and had an opportunity to study several fetal, neonatal, and juvenile whales: 1) Two fetuses collected at Barrow during the springs of 1969 and 1970; 2) one fetus collected at Wainwright in the spring of 1978; 3) one fetus collected at Barrow in the spring of 1976; 4) two neonatal calves taken at Barrow during the springs of 1969 and 1973; and 5) a young-of-the-year calf taken at Barrow in October 1964 (Table 1). None of the Alaskan fetuses collected to date have been dissected for

study. I also received additional information from the Eskimos about embryos, fetuses, and young calves that they had examined. The objective of this paper, therefore, is to describe the external morphology of these young

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Table 1.—Morphometric measurements of developing bowhead whales.

Morphological features	Fetus	Fetus	Fetus	Fetus	Neonatal	Calf
Sex	Male	Male	Male	Female	Male	Male
Specimen number ¹	4398	4392	78WW1	76B5F	4478	4329
Length (cm)	13.4	23.5	37.5	128.0	—	—
Tip of snout to (cm)						
Tip of lower jaw	0.9	0.1	1.6	2.5	6.0	—
Blowhole	2.1	4.0	5.8	18.5	74.0	110.0
Eye	3.6	6.5	11.0	33.0	104.0	190.0
Gape	3.3	6.0	11.5	35.5	102.0	180.0
Ear	4.2	7.2	12.5	—	120.0	—
Insertion of flipper	4.3	7.5	13.5	41.0	133.0	245.0
Axilla	5.1	9.0	15.5	50.0	152.0	—
Umbilicus	7.2	13.0	—	71.0	245.0	—
Reproductive slit (center)	—	—	—	88.5	292.0	—
Anus	9.7	15.5	25.6	91.5	342.0	—
Peduncle	12.0	22.0	34.4	113.0	424.0	—
Notch of tail	13.4	23.5	37.5	128.0	460.0	600-640
Diameter (maximum)	2.7	5.0	—	28.9	91.0	160.0
Circumference at (cm)						
Blowhole	4.5	9.6	—	72.0	—	—
Flipper insertion	7.0	13.5	23.5	92.0	—	—
Umbilicus	6.7	13.7	—	85.0	—	—
Anus	4.3	6.0	—	50.0	—	—
Peduncle	2.0	—	5.9	18.0	—	—
Flipper (cm)						
Anterior length	2.0	3.3	5.4	19.1	75.0	92.0
Posterior length	1.5	2.4	4.4	14.0	56.0	70.0
Width at body	0.9	1.1	2.8	—	27.0	—
Width, maximum	1.0	1.3	2.0	8.5	32.0	41.0
Flukes (cm)						
Anterior length	1.4	2.5	—	31.0	—	—
Posterior length	0.9	2.5	—	21.0	72.0	—
Width, maximum	1.4	2.1	4.4	13.0	43.0	—
Span	1.8	5.0	9.2	41.0	137.0	—
Umbilicus diameter (cm)	—	—	—	3.5	9.0	—
Additional data						
Hump, length and width (cm)	—	—	—	0.6 × 10.0	—	—
Percentage maximum diameter of total length	21.0	21.0	—	22.5	19.0	—
Weight (kg)	0.29	1.6	9.0	25.0	—	—

¹Specimen numbers 4398, 4392, 4478, and 4329 are those of the author, while 78WW1 and 76B5F are NMFS specimen collection numbers.

bowheads as it relates to early development of the species.

Fetuses

Early Fetuses

Fetus, 13.4 cm Long

A pregnant, 13.0 m female (author's specimen number FED 4398) was harvested near Barrow on 10 May 1970, while I was at Point Hope, Alaska. On returning to Barrow 2 days later, I went to the butchering site and found a 13.4 cm male fetus among the entrails (Fig. 1; Table 1). In the course of slitting the integument of the uterine horn, the fetus in a simple, shapeless water sac fell out, and the frail umbilicus connection to the fetus broke. Anterior to the umbilicus attachment was the 2.7 × 2.0 cm yolk sac. Except for the cervical flexure, the longitudinal axis of the

¹Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Processed rep., 80 p., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115.

fetus was straight. The head of the fetus was bulbous with a fontanelle at the top, and it appeared beaked, as in a dolphin (Fig. 1). The blowhole site was immediately anterior to the elevated cranium, at a "low point" on the rostrum. The rostrum was flattened with a gradual down-curve distally, as in a chicken's beak. The tongue was flat and lacked scallops; on the underside the frenum lacked 1.0 mm of extending to the tip. There was no indication of baleen. The lower lip was scarcely more evident than the upper. Black pigmentation of the iris was discernible through the closed but translucent eyelids. Rudimentary ear pinnae were visible directly behind the eyes and slightly above the proximal joints of mandible and humerus.

The flippers were well formed, folded diagonally across the breast, and lacked 4.0 cm of meeting midventrally. Digit numbers II to V showed as ridges on the flipper's surface. The small flukes, shaped like a blunt wedge that pointed posteriorly, had no notch. The trailing edge, like that of the flippers, was not sinuous. There was no trace of hind limb buds. The caudal ridge was barely evident. The penis protruded from the lower abdominal wall and there was no prepuce. The skin was not pigmented.

Fetus, 23.5 cm Long

On 2 June 1969, I collected a 23.5 cm long male fetus from a 16 m long female (FED 4392) taken near Barrow (Table 1; Fig. 2). The cranium of the fetus was bulbous and soft. The lower jaw was shorter than the rostrum, and the profile of the head resembled that of a dolphin. However, the flippers, flukes, and lower jaw showed additional development toward adult structures. Of particular interest were the flippers. The characteristic four digits of the bowhead, II, III, IV, and V, were clearly visible and even included a trace of phalanges, particularly in digit V. Proximal to the wide-spreading V digit was the pisiform cartilage, an additional aid in strengthening and broadening the paddle-shaped flipper. The flukes had a terminal notch, were bluntly wedge-shaped, and pointed anteriorly. The

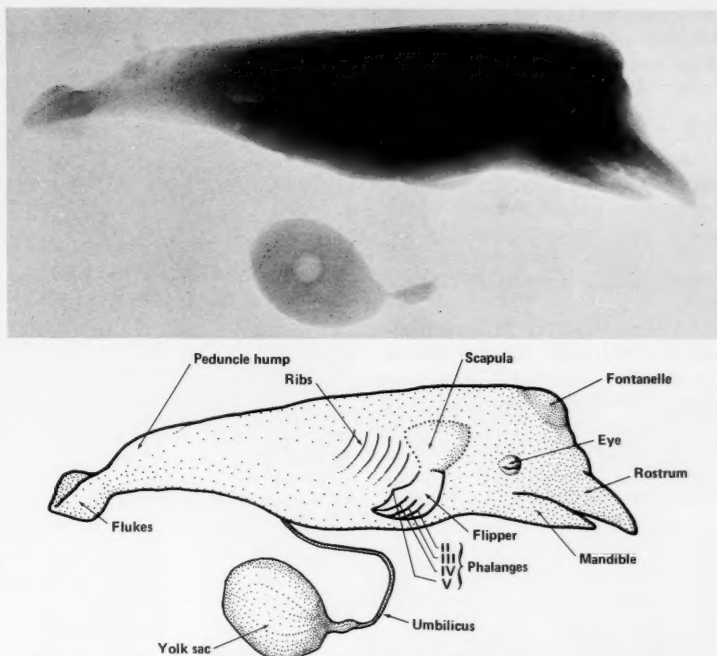


Figure 1.—X-ray (positive print) of a bowhead whale fetus 13.4 cm in length. Externally, the fontanelle, yolk sac, and hump are evident. The phalanges, scapula, and ribs show through the semi-transparent body wall. Photograph by F. E. Durham.

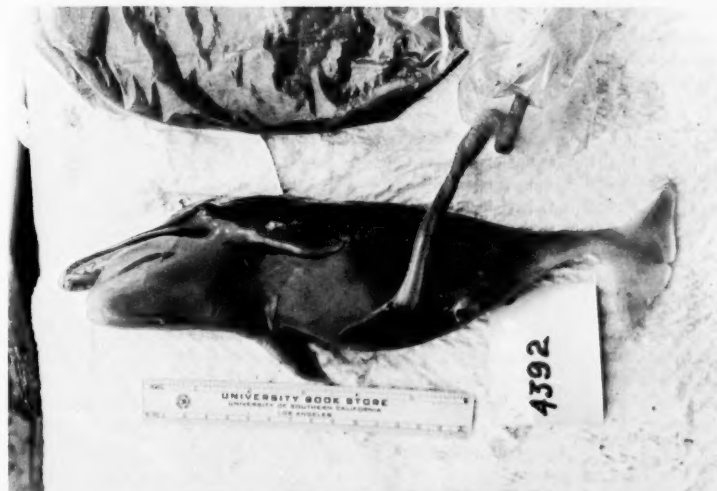


Figure 2.—Ventrolateral view of a 23.5 cm bowhead fetus, showing additional development toward adult structures, particularly in the flukes. Photograph by F. E. Durham.

penis protruded from the lower abdominal wall, and there was no prepuce. There was no baleen present and no pigmentation of the skin.

Fetus, 37.5 cm Long

Three other small fetuses have been reported. Photographs of two of the fetuses were studied and my observations of discernable morphological features are reported herein; no information is available, however, on the third fetus.

A 37.5 cm fetus (Fig. 3) from a pregnant 16.3 m female (National Marine Fisheries Service [NMFS] specimen number 78-WW-1), harvested on 6 May 1978 at Wainwright, Alaska, was collected and preserved by the whaling captain for a proposed local museum. Although I have not had the opportunity to examine this fetus, measurements obtained by NMFS personnel are presented in Table 1. Examining a photograph of the fetus (Fig. 3), one notes that the profiles of body and appendages have changed little from those of the 23.5 cm fetus shown in Figure 2. Also evident is a hump on the tail and a ventral keel that extends from anus to peduncle.

A resident of Wales, Alaska, informed me that during her childhood her father removed a fetus, estimated to be about 61 cm in length, from a pregnant bowhead he landed there during one spring whaling season in the early 1900's².

Fetus, 77.5 cm Long

A 77.5 cm long fetus is on deposit at the Peterhead Museum, Peterhead, Scotland. The fetus was believed to have come from a whale taken in Davis Strait, Canada. From a photograph, I observed that the trailing margin of both flippers and flukes appeared sinuous. The notch of the fluke and the trailing tips appeared near adult proportions. A trace of a dorsal hump appeared near the middle of the caudal peduncle. The cranium was the highest part of the head. The blowhole site was on a faint



Figure 3. — A 37.5 cm bowhead fetus collected 6 May 1978 at Wainwright, Alaska; the whaling captain had it preserved and is holding for a proposed local museum. Photograph by Larry Rockhill.

prominence at the base of the flat rostrum which curved downward near the tip. The upper jaw extended farther forward than the lower.

Fetus, 128 cm Long

On 3 September 1976, a 128 cm long female fetus (Fig. 4a) was collected by NMFS biologists from a 17.3 m bowhead (76-B-5F) which had been taken near Barrow. I examined the frozen fetus on 9 June 1977, at the National Museum of Natural History, Smithsonian Institution, Washington, D.C. The maximum girth of the fetus was 92.0 cm and the maximum diameter was 28.9 cm (Table 1). The maximum girth represented 72 percent, the maximum diameter 22.5 percent, and the head 30 percent of the fetus' total length.

The cranium and rostrum clearly resembled the balaenid adult form (Fig. 3). The dorsal elevation showed remains of the bulbous cranium. Immediately anterior to and medially on the base of the depressed rostrum were the paired blowholes. They were 1.5 cm long, sinuous, slanted abruptly medio-anteriorly, and appeared to be sealed

shut (Fig. 4a). The prognathic jaws were frozen together, preventing me from determining if baleen was present. The distal tip of the rostrum was curved downward as it is in older bowheads. The lower lip had enlarged to near-adult proportions (Fig. 4b). The flippers were firmly positioned against the sides and revealed the four digits through the skin and thin flesh.

The anal plate (containing surface openings for the digestive, urinary, and reproductive systems) was similar to but more elaborate than that of an adult female bowhead. The anus was 1.5 cm posterior to the genital slit. Two oval mammary slits were 4.0 cm apart, and lay opposite the center of the genital slit. Lateral and posterior to the mammary slits was a pair of pits 6.5 cm apart that were partially connected by an arc of whitish surface fibers, suggesting the position of the primordial pelvic girdle or interpelvic ligament (Fig. 4c). Slight, protruding structures, similar in position to the above pits, were photographed on an adult female (79-WW-1) taken in the spring of 1979 at Wainwright, Alaska (Fig. 5). Their location

²Katy Tokeimma, resident, Wales, AK 99783, pers. commun. 1967.

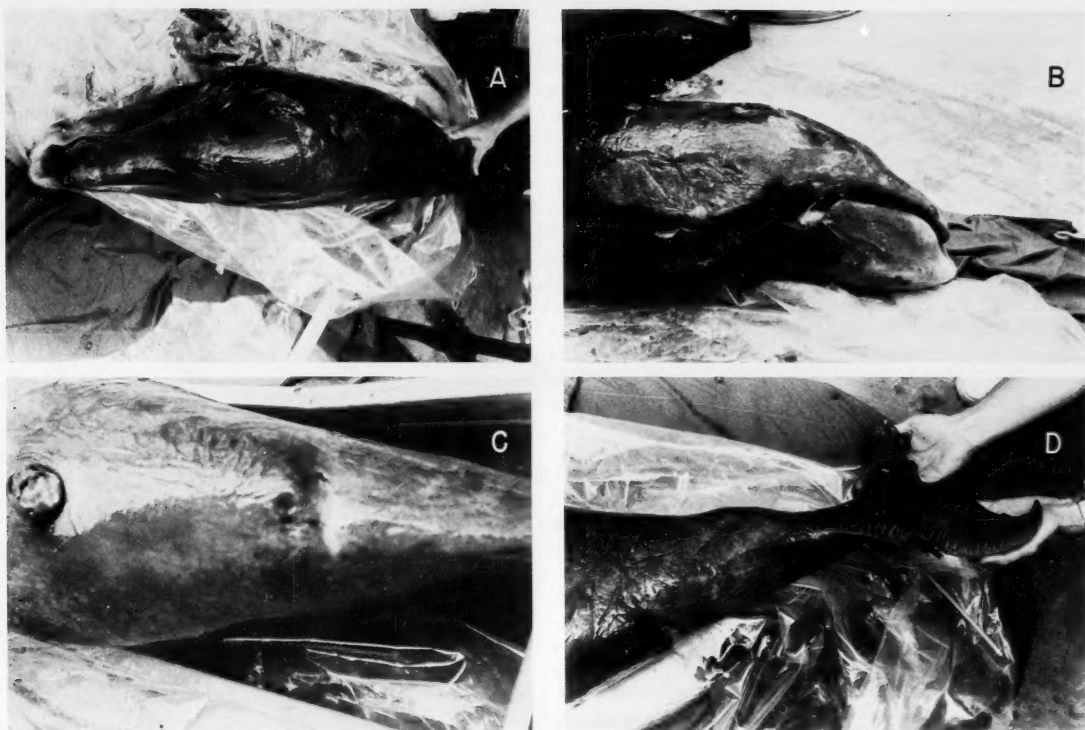


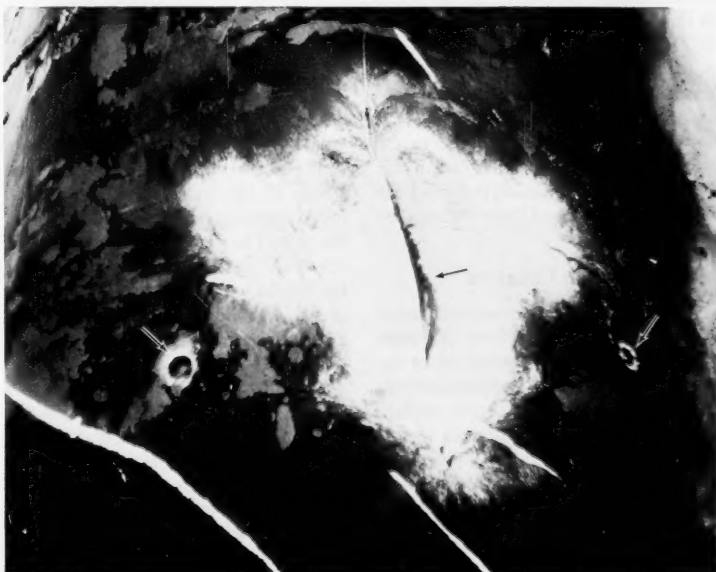
Figure 4.—A 128 cm midterm bowhead fetus showing: A) dorsal view of head; B) lateral view of head; C) ventral view showing umbilicus and anal plate; and D) view of caudal section showing the dorsal hump or ridge and shape of flukes. Photographs by F. E. Durham.

Figure 5.—Ventral portion of a 1,463 cm bowhead whale (79-WW-1) showing the anal plate (white patch surrounding it) and what are believed to be bulging femori (white arrows). Photograph by Carl Peterson, NMFS.

and appearance suggest that they were bulging femori. The author and NMFS biologists have examined over 200 bowhead whales since 1961, but these were the only individuals showing surface indications of a pelvic girdle and appendages.

Caudally, the dorsal hump or ridge, 0.6 cm high, extended 10 cm anteriorly from a point 6.0 cm anterior to the caudal peduncle (Fig. 4d). The flukes were too distorted to show the margin clearly.

The hair pattern was similar to that of adults and consisted of: 1) Three terminal patches—a black, 2 × 3 cm rostral



patch with hairs just emerging, and two teardrop shaped lateral jaw patches; 2) a row of seven black "beads" or pigment spots, each containing a single hair, 8 mm in length, that extended along the side of each mandible; 3) a double row of hairs parallel to the midline of the rostrum (six on the right side and four on the left) located on the anterior half of the rostrum; and 4) a double arc (one over each blowhole) of 13 hairs, each longer than those on the jaw.

Although the color pattern of the fetus may have been changed by freezing, its back was now black and the sides were lighter with a pinkish-gray mottling. The chin was a muddy white. The anterior end of the lower lip, the throat, and belly were a reddish gray. The flippers were dark with white, dendritic markings along the leading edge. The area posterior to the umbilicus was paler than the surrounding skin. There were white rays in starburst form around the mammary slits, particularly the left one.

Neonates

Five newborn or neonate bowheads have been taken by Alaskan Eskimo whalers in recent years. I did not have an opportunity to examine three of these animals. Two were reported taken at Point Hope, Alaska, one on 22 May 1969 and one on 3 June 1971. A third newborn, taken at Wainwright, Alaska, on 28 May 1970, was reported by the Eskimos to have been an albino. It was a 447 cm long female estimated by the whalers to have been about 1 month old. I examined the remaining two newborn bowheads landed and these will now be described.

Neonate, Length Unknown

The first newborn I examined, taken on 27 May 1969 (FED 4390), had been cut up and partly distributed before my arrival at the village. No measurements had been taken. Because the captain claimed the head and peduncle for his share, I was privileged to examine these parts at his home on 28 May. He also donated the skull (137 × 64 cm) for the bowhead collection at the Los Angeles County Museum.

The cranium was no longer bulbous. The blowholes were not elevated. The gray colored "baby skin" with black reticulations was underlain by 7 cm of "dry" blubber, that is, the unsaturated fats did not ooze out as in older bowheads. I also located and examined one flipper which was stubby, slightly arched, and had a scalloped posterior margin. A profile drawing of the peduncle shows the extreme development of the caudal hump often associated with ingutuks (Braham et al., 1980). The tongue was pink, with a median, longitudinal groove 20 × 9 cm in length and 5 cm deep, near the tip. A few wart-like papillae margined the groove. Near the margin was a row of about 20 short transverse ridges on each side. The frenum allowed the distal 8 cm of the tongue to be free. A gap of 11 cm separated the two rows of baleen at the front of the mouth. This gap, apparently for holding the dam's nipple between the tip of the tongue and palate, seemed ideal for nursing (Slipper, 1962). Of the baleen plates on the right side, most were 7 cm long plus another 11 cm within the gum. The juncture between natal and nursing baleen had not yet become evident. The lower jaw was again shorter and was proportionally wider than the upper. The posterior margins of the flipper and flukes were sinuous.

Neonate, 460 cm Long

The second newborn that I examined was a 460 cm male (FED 4478) taken near Barrow on 7 June 1973 (Fig. 6a; Table 1). It was bluish gray with muddy-white markings, particularly on the chin. The pigmented skin had two 2 cm thick layers, which is about twice the thickness of the single layer of skin found in juvenile and adult bowheads. The highest part of the head, the cranium, was no longer bulbous and was demarcated from the trunk by a depression at the neck. The blowholes were not elevated and were at a lower level on the base of the somewhat flattened rostrum, the profile of which was similar to that of a rorqual. The lower jaw was shorter and wider than the upper. The trailing margins of the flippers

and flukes were sinuous (Fig. 6b, c). The mammary slits were opposite the Y-shaped posterior end of the genital slit (Fig. 6d). The dorsal hump or ridge, which is at its greatest development during this stage of growth, was prominent on the peduncle (Fig. 6e). The ventral area, including umbilicus and anal plate, is shown in Figure 6d. Because of the size and condition of the umbilicus, I estimated the animal to be 3 days old. There were 352 plates of baleen on one side, most of them 18.0 cm long, including that portion within the gum.

Young-of-the-Year

The smallest bowhead of the 1964 autumn season (FED 4329) was landed at Barrow on 2 October (Table 1). The posterior half of the carcass was butchered before I arrived, but the captain estimated the total length to be about 610 cm. Because the cleaned skull measured 1.8 m long, and because the ratio of head to total body length is 1:3 in most harvested bowheads, the estimated length of the calf appears to be fairly accurate. Its slender body was dark gray with only a faint gray patch on the chin. The "baby skin" had been shed and the remaining layer varied in thickness from 1.9 to 2.2 cm. The blubber was oily and ranged in thickness from 14 cm on the shoulder to 18 cm on the back. The rostrum was slightly arched and the blowholes were at the highest point on the head. One side of baleen measured 140 cm in length and anteriorly there was a conspicuous and slightly worn natal tip 6.5 cm in length. The anal plate, typical of young males, showed a retracted, 40 cm long glans penis. A pair of mammary slits, each with a nipple as in females, was lateral to the base of the penis, and 50 cm anterior to the anus. In addition, there was a secondary mammary slit adjacent to the right one, but without a nipple. Subcutaneous vestigial muscles, which usually are found in neonatal calves, were present around the nipples. The stomach was empty, suggesting that the animal was recently weaned, because juveniles and adults usually have some partially digested food in their stomachs during the autumn.

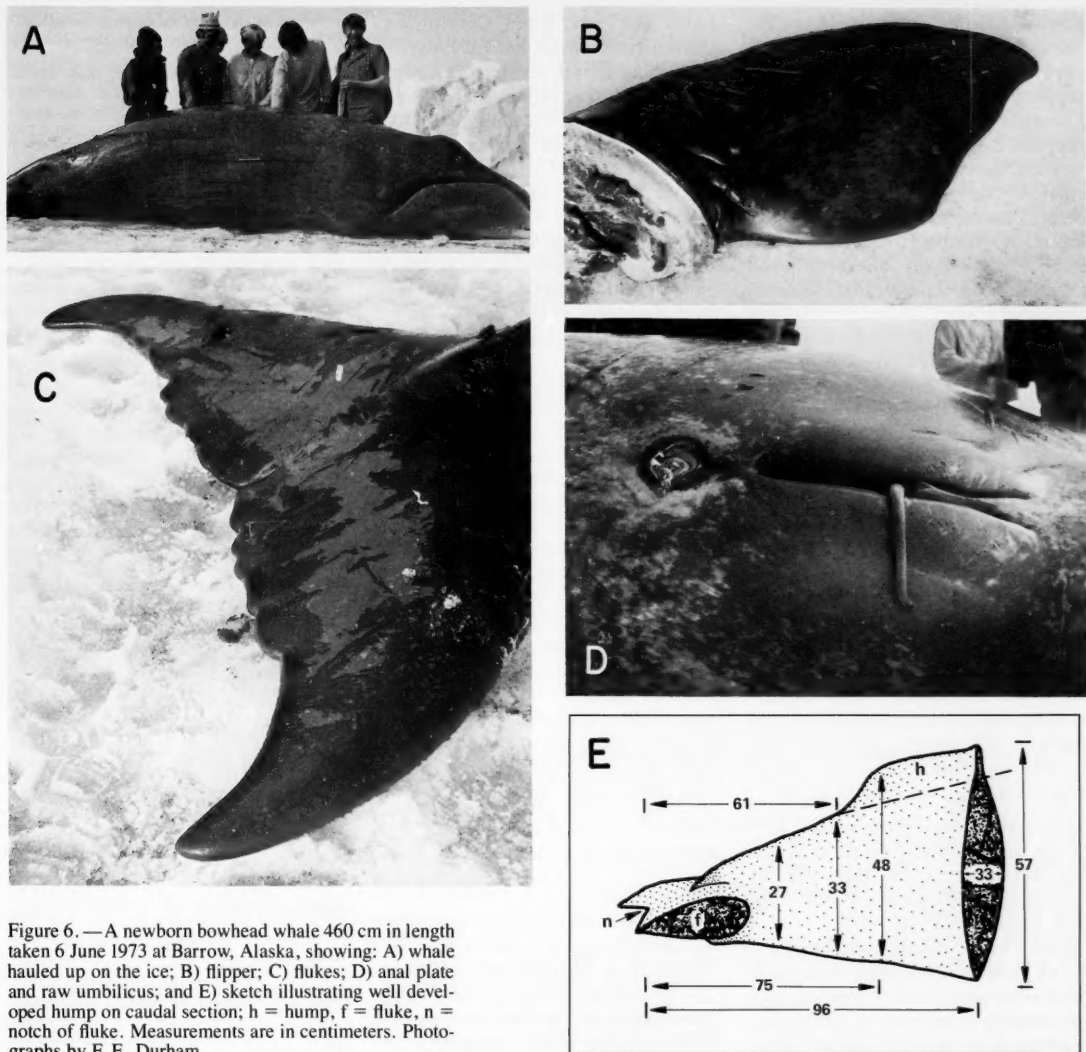


Figure 6. — A newborn bowhead whale 460 cm in length taken 6 June 1973 at Barrow, Alaska, showing: A) whale hauled up on the ice; B) flipper; C) flukes; D) anal plate and raw umbilicus; and E) sketch illustrating well developed hump on caudal section; h = hump, f = fluke, n = notch of fluke. Measurements are in centimeters. Photographs by F. E. Durham.

Two additional bowhead calves, both estimated by Eskimo whalers to be 610 cm in length, were taken during the autumn season. One was taken east of Barrow near Cooper Island on 19 October 1966, and the other was captured on 23 October 1973, 16 km north of Point Barrow. No additional information is available on these two bowheads.

Conclusion

Although the number of specimens collected is not large, the information reported in this preliminary paper is the first descriptive material on early development of the species. Intensified interest in the reproductive cycle of the bowhead whale has prompted early publication of data on this subject. Pre-

sumably the intensive research program now being conducted by the NMFS will provide additional material in the near future.

Acknowledgments

I am deeply indebted to the many Eskimo whaling captains who generously shared with me their camps, specimens, and information on

bowhead whales. The Naval Arctic Research Laboratory at Barrow, Alaska, gave me institutional and individual support. The National Marine Mammal Laboratory, NMFS, Seattle, Wash., supplied data on fetuses and provided financial support, as did the Arctic Institute of North America, Calgary, Alberta, Canada, and the Office of Naval Research, Washington, D.C. I also thank James Mead, Jane Small, and David Schmidt of the National Museum of Natural History, Smithsonian Institution, Washington, D.C., for courtesies extended in making it possible for me to examine a frozen fetus on deposit there.

Larry Rockhill, Field Coordinator, University of Alaska, X-CED Program, Rural Education Development Center, Barrow, Alaska, provided the photograph of the 37.5 cm long fetus from Wainwright, Alaska.

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Observations of Bowhead Whales During Spring Migration

GEOFFRY M. CARROLL and JOHN R. SMITHISLER

Introduction

Each spring bowhead whales, *Balaena mysticetus*, of the western Arctic stock travel through breaks in the sea ice, migrating from their winter grounds in the Bering Sea to their summer grounds in the Beaufort Sea (Braham et al., 1980). These breaks in the ice, or leads, form when winds blow the moving pack ice away from landfast ice, creating a flow zone of open water and broken ice generally parallel to the shore. If conditions allow, most bowheads follow these nearshore leads while migrating along the northwestern coast of Alaska. This provides an excellent opportunity to observe their behavior.

There is little published information on the behavior of bowhead whales. Some whaling captains (Scoresby, 1820; Scammon, 1874; Cook, 1926; Bodfish, 1936) included comments on whale behavior in reporting their experiences in Arctic waters. Tomilin (1957), Slepšov (1961), Maher and Wilimovsky (1963),

McVay (1973), Marquette (1976, 1978), Everitt and Krogman (1979), Rugb and Cabbage (1980), Gilmore¹, Foote², Durham³, Fiscus and Marquette⁴, Braham and Krogman⁵, and Mar-

¹Gilmore, R. M. 1951. The Arctic right whale, Greenland whale, or bowhead. Unpubl. manuscript. [Vol. 15, Encyclopedia Arctica], 71 p. Avail. Dartmouth College Library, Hanover, NH 03755.

²Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpubl. manuscript, 73 p. Geogr. Dep., McGill Univ., Montreal, Que., Can.

³Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus*) in the western Arctic. Unpubl. manuscript, 93 p. Dep. Biol., Univ. South Calif., Los Angeles, CA 90007.

⁴Fiscus, C. H., and W. M. Marquette. 1975. National Marine Fisheries Service field studies relating to the bowhead whale harvest in Alaska, 1974. Processed rep., 23 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

⁵Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

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quette⁶ include comments on bowhead behavior.

During April, May, and June 1975-78, National Marine Fisheries Service (NMFS) biologists were stationed at Point Hope and Point Barrow, Alaska, to census the bowhead whale population, maintaining a 24-hour watch (ice and weather conditions permitting) from camps established on the landfast ice (Braham and Krogman, footnote 5; Braham et al., 1979). They recorded the behavior of bowheads during their northward migration in the nearshore lead past the ice camp. Two categories of behavior were recorded: 1) General migrating behavior directly associated with rate and direction of migration, group size, size class distribution, dive profiles, and movements of whales through constantly changing ice fields; and 2) "extra-migratory" behavior such as reaction to human disturbance,

⁶Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-76, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

resting, exuberant displays, and feeding. The objective of this paper is to describe the behavior of migrating bowhead whales as interpreted from observations, literature, and conversations with Eskimo whalers.

General Migratory Behavior

Rate and Direction of Migration

When ice was not obstructing their passage, bowhead whales moved through the nearshore lead at a steady rate, seldom altering course. Depending on the direction and velocity of the water current, their rate of travel relative to the observers ranged from 1 to 11 km/hour. Nearly all the whales traveled northeastwardly; fewer than 1 percent traveled in the opposite direction. When they traveled southwest it was usually because of closed leads stopping their progress to the northeast.

Group Size

During the spring migration, bowheads usually travel alone, though they are occasionally seen in pairs and small groups, with individuals separated by a few meters. Of 2,406 bowheads that we observed over the 4 years, 1,815 (75.4 percent) were traveling singly; 470 (19.5 percent) were in pairs; 105 (4.4 percent) were in groups of three, and 16 (0.7 percent) traveled in groups of four animals. Usually one individual of a pair was distinctly smaller than the other but not small enough to be a calf-of-the-year. Foote (footnote 2) suggested that these may be young whales that stay with the cow for more than 1 year.

During the migration there were noticeable peaks in the numbers of whales passing our camps. These peaks, or pulses, could be thought of as loosely associated groups of whales, possibly in communication with each other. This could have been a function of ice conditions, as bowheads sometimes accumulate in open water areas until a blocked lead becomes passable. However, we recorded the most distinct pulses of whales in 1978, when the lead was open all season, suggesting that there may be pulses inherent in the migration of these whales—pulses which

are altered but not caused by ice conditions. The Eskimos describe three major pulses each spring. Durham (footnote 3) concluded from his bowhead catch statistics that there were four pulses. Our results show a varying number of pulses from year to year with no strong consistency except that two pulses were distinct between 15 April and 30 May each year from 1976 to 1978 (Braham et al., 1979; Krogman, 1980).

Size Class Distribution

Smaller and presumably younger whales were more prevalent early in the season. From mid-April through early May, when bowheads first appeared in the leads off Barrow, most of the whales were judged to be small. From late May to early June, the majority of whales were large. This is consistent with observations made by Eskimos. Calves-of-the-year have been seen migrating with their mothers during April, May, and June, indicating that at least some calves were born shortly before or during the spring migration (Braham et al., 1980). Small calves generally stay close to their mothers' sides and are difficult to see particularly if they are on the offshore side of the mother. On two occasions, very small calves were seen riding their mothers' backs, apparently grasping the mothers with their flippers.

Dive Profiles

Bowheads progressed with long, presumably deep, sounding dives interspersed with shorter periods near the surface during which they surfaced, exhaled (ventilated or "blew"), inhaled and dove several times in succession. Viewed from the ice, the prominent bowed head and blowhole appeared first, usually accompanied by the high "V" shaped vapor trail of an exhalation or "blow." This was followed by the broad, rounded back, lacking a dorsal fin, which appeared as the head submerged. Several seconds after the back submerged, the head reappeared beginning the next roll. After the last blow in a series, the whales arched their backs sharply before sounding. Occasionally bowheads were seen to display flukes on a sounding dive.

Each whale observed surfaced 2-14 times in a dive sequence, beginning with the first blow and ending with an apparent sounding dive. Of 63 observations of rolls from undisturbed whales from 1975 to 1977, the mean number was 6.57 ± 3.08 (standard deviation, SD) per dive sequence. Of 41 recorded dive sequences during 1978, the mean number of blows per rise was 6.53 ± 2.84 (SD). Undisturbed bowheads most often ventilated seven to nine times per dive sequence, but it was not unusual for them to blow as few as two or three times (Fig. 1). However, a blow is not always visible each time a whale rolls, and thus the data may be biased slightly downward.

For determining the average time that whales were at or near the surface, only the 1978 data were used because of greater precision obtained in timing observations with the use of time-lapse digital stopwatches. Surfacing sequences were recorded for eight bowheads that provided a total of 31 timed periods. The mean time at the surface for these whales was 4.7 seconds (2.0 SD). Mean time below the surface between blows, determined from 30 timed periods for all eight whales, was 10.8 seconds (5.2 SD).

The mean total time a bowhead was visible to observers (30.9 seconds), was derived by multiplying the mean number of rolls by the mean time of each roll. The mean duration of a rise, 91.2 seconds, was determined by adding the mean time above the surface to the mean time between blows. This was

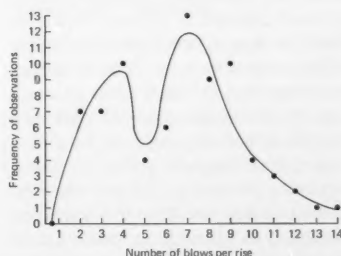


Figure 1.—Frequency of blows per rise for bowhead whales observed during spring migration near Point Barrow, Alaska, 1975-77.

the time between sounding dives when a whale was at or near the surface and presumably visible from an aircraft.

Of 63 sounding dives timed during 1975-78, the estimated mean duration of such dives was 15.6 minutes (5.0 SD). Sounding dives as short as 3.0 minutes and as long as 26.7 minutes were recorded.

Using the above results the percentage of time spent at and near the surface was calculated. Combining the 15.6 minutes mean sounding dive time with the derived 91.2 second mean rise time, a time of 17.1 minutes was calculated for the complete cycle. On the basis of these calculations some part of the whale was visible above the surface 3.1 percent of the time and was above or near the surface between sounding dives 8.4 percent of the time. The whales were below the surface and not visible from ice level 96.9 percent of the time and not visible from an aircraft 91.6 percent of the time. This is consistent with the findings of Braham and Krogman (footnote 5) that more whales per effort (time) were seen during aerial surveys than from counting camps.

Sounding dive times of three cow-and-calf pairs ranged from 5.9 to 7.0 minutes, with a mean duration of 6.6 minutes. The calf usually surfaced with its mother and often blew twice during a surfacing period. Cows with calves appeared to adapt their surfacing patterns to the diving capabilities of their offspring.

Eskimo whalers are aware of the breathing pattern of undisturbed bowheads and utilize this knowledge to maneuver their boats into position where they can strike the animal when it surfaces. Hunters at Barrow often note the time that a bowhead sounds and utilize radios to notify crews farther along the lead to watch for it to resurface 15-20 minutes later. If a whale's normal breathing pattern was disrupted, for example if it dove because it was being pursued by Eskimo whalers, it took fewer breaths and surfaced sooner than during an undisturbed sounding dive. Foote (footnote 2) stated that wounded, frightened, or otherwise extremely disturbed bowheads could stay underwater for up to 1.25 hours.

When they resurfaced, such whales were lethargic and slow to react.

Maneuvering in Ice

During their northward spring migration, bowheads encounter constantly changing ice conditions. Leads open or close as the wind and/or current shifts throughout the season, or refreeze during periods of calm, cold weather. When whales encounter a partially closed lead interposed with polynyas (areas of open water surrounded by ice), they adjust their diving and surfacing sequences to the size and location of the open water. Whales encountering a small polynya would surface and blow as many times as space allowed while traveling at normal speed; then they would dive at the far edge of the polynya. If another polynya was close, the whales would surface there, take a few more breaths, and continue on. In this way they were able to move steadily through flaw zones that were mostly covered with ice.

It is not known how bowheads maneuver or navigate from one polynya to another. Because the irregularly shaped edges of pack and fast ice do not usually fit tightly together, there is generally open water and/or patches of thin ice seaward of the shorefast ice edge. The subsurface of the flaw zone seems sufficiently different in appearance from solid pack and shorefast ice that whales could follow it and successfully find open water or thin, breakable ice. Using scuba gear we have observed that holes in the ice and areas with no snow cover (i.e., new ice) are easy to detect when visibility is fair to good, as there is greater light penetration there. Presumably, these areas are apparent to the whales.

During the spring of 1978 near Point Barrow, Smithhisler observed three bowheads surfacing together near the southwestern side of the only polynya within several miles. The opening was about 150×800 m, with the longest axis perpendicular to the edge of the frozen lead. The three whales dove at the same time and, minutes later, surfaced within 10 seconds of one another on the northeastern edge of the polynya

several hundred meters apart. They blew several times along the edge of the ice, dove within 10 seconds of one another, and were not seen again. It looked as if the whales had separated to search a wider area. These simultaneous movements suggested to us that the whales were somehow communicating with one another.

Occasionally a lead closed so tightly that the whales' progress was hindered, and the polynyas were too far apart to be reached in a single dive. Some whales proceeded though the lead appeared closed, but fewer did so than when the lead was open. We heard blows though there was no visible open water. It appeared that the whales dove, searched, and, if they did not find another polynya, returned to mill in the available polynya, thus keeping the surface water from freezing. Bowheads can break new ice as thick as 22 cm⁷. Sea ice is more flexible than freshwater ice, and bowheads and white whales, *Delphinapterus leucas*, have been sighted pushing up young ice, forming hummocks to breathe.

Tomilin (1957) mentioned several instances of bowheads being trapped in the ice in Soviet waters. Sleptsov (1961) stated that bowheads have been trapped in heavy pack ice in various gulfs along the Chukchi Peninsula, U.S.S.R., and that a mass mortality of bowheads occurred in Karaginskiy Bay, U.S.S.R., in 1932. Unfortunately, no other details were available. Southwell (1898) quotes Eschricht and Reinhardt as saying that bowheads perished in the ice in Disko Bay near Greenland. Bowhead whales, then, are not always successful at finding or forming a breathing hole in the ice.

For periods of hours or days, whales seemed to follow a similar course, surfacing on the same side of the lead and often in nearly the same location as the whales that preceded them. There could be several explanations for this. Foote (footnote 2) interviewed some Eskimos who believed that whales follow a cloud of bubbles left by the preceding whale. Water currents, which at times appear

⁷J. J. Burns, Alaska Dep. Fish Game, Fairbanks, AK 99701, pers. commun.

to move in different directions in different parts of the lead, may influence their direction of travel. Bowheads tended to surface in bights (small embayments in the ice); their behavior may then be related to the way a lead forms and the shape it assumes.

Extra-Migratory Behavior

Reaction to Human Disturbance

When bowheads are pursued by Eskimo whalers their usual reaction is docile escape. When they perceive something as threatening, bowheads quickly dive and do not resurface in the immediate area. At the Point Barrow ice camp in 1976, Carroll was observing a partially closed lead with several polynyas in view. Bowheads and white whales traveling through the lead surfaced in one particular polynya even though there were larger and apparently equally suitable openings in the ice nearby. The whales surfaced in this opening at a rate of about one every half hour, proceeded north to the far edge of the polynya, and then sounded. Carroll had been observing this activity for 3 hours when an Eskimo hunter fired a shot while a bowhead was surfacing within view of the observation site. The whale dove and was not seen again. During the next 3 hours of observation, no bowheads surfaced in or near that polynya, though an observer who was watching the lead 3 miles to the northeast reported that bowheads passed steadily all day, even several hours past the time they stopped surfacing in front of Carroll. We speculate that the startled bowhead somehow communicated a warning signal, and following whales avoided that particular polynya.

Using a hydrophone in the lead at Point Barrow, NMFS personnel distinctly heard sounds made by aircraft, snowmobiles, and outboard motors. Bowheads do not seem to be habituated to machine sounds. Aircraft flying below 152 m, particularly helicopters, sometimes appeared to cause bowheads to make a sounding dive. Walking or operating a snowmobile near the edge of the lead appeared to cause whales to avoid surfacing near the disturbance.

Outboard motors seldom are used in spring whaling at Barrow or Point Hope because they cause the whales to avoid the area. During autumn whaling, Barrow and Barter Island hunters are occasionally successful at taking bowheads from boats propelled by outboard motors because the sea is generally clear of pack ice and quite rough. The whalers think that this turbulence masks the sound of the outboard, thus allowing them to approach the whales.

Oars and paddles used to propel boats can be a disturbing factor in the hunt for bowheads. A whale which is being approached by hunters will usually dive if a paddle strikes the side of the boat or makes a loud splash in the water. Bodfish (1936), a commercial whaler, stated that bowheads reacted to the disturbance of oars in the water and that he was most successful when hunting under sail. Eskimo whalers at St. Lawrence Island have retained the method of using skin boats rigged for sailing when pursuing bowheads. Many skilled Eskimo whalers wait for a whale to blow before they slide their boats into the water, believing that the blow will mask the sound of a boat scraping across the ice.

Eskimo whalers also believe that bowheads have good eyesight. Accordingly, the hunters take great care not to be seen by the whales. Traditionally, clothing and boats used on the ice blend into the white surroundings. Bright colors, particularly red, are seldom worn on the ice. Whalers cover bright red floats that are attached to harpoons for fear the whales will see the color and flee. Flat pieces of ice frequently are set on edge in front of whaling camps to reduce the possibility of whales seeing movements of the Eskimos at their camps. The whalers also avoid standing on mounds near the ice edge, thus creating dark silhouettes which they feel frighten the whales away. Eskimo whalers attempt to approach bowheads head-on or from the rear to decrease the chance of the whales seeing the boat with their laterally located eyes.

All whales do not react in the same way to an approaching boat. Smaller whales seem less wary, as boats can occasionally slide right up on their

backs before they react. Also, smaller whales tend to travel closer to the near-shore edge of the lead than larger ones and are thus more susceptible to attack by the hunters. It is partly because of this availability along with the deliberate selection of small whales by most hunters (Marquette, footnote 6), that up to 85 percent of the whales harvested are immature (Maher and Wilimovsky, 1963).

On rare occasions bowheads react aggressively. Near Barrow, in 1976, an umiak (skin boat) was capsized by a startled whale that apparently was resting when the boat approached; one of the crew was drowned. Also, near Barrow in 1977, a resting bowhead was startled when struck and one of the skin boats was broken when it ended up partially in the whale's mouth. Eskimo whalers say that bowheads that are copulating or courting are particularly dangerous and these whales are seldom approached by whalers.

Resting

Bowheads were occasionally seen in an apparent resting state (Fig. 2). They surfaced to blow and submerged in one spot instead of proceeding forward as during normal migration. Sometimes they stayed at the surface taking several shallow breaths before slipping beneath the water. Often there was no visible blow although a blow could be heard. Some whales exposed only their blowholes above the surface while staying in one place. Bowheads were seen apparently resting for over an hour on four occasions.

"Exuberant" Behavior

Approximately 95 percent of the time when bowheads passed our observation sites near Point Barrow and Point Hope they exhibited the normally expected migratory surfacing patterns. Occasionally they engaged in other activities.

Bowheads breach, leaping out of the water and exposing up to two-thirds of their bodies above the surface before falling back on their bellies, backs, or sides (Fig. 3); spyhop, exposing the anterior third of their bodies above the

surface and sliding back tail first; lobe-tail, hanging vertically in the water with only the tail above the surface and slapping the water several times with their flukes; swim with one flipper above the surface and slap the water with it; lunge; and swim on their backs and sides. One whale was observed 19 May 1977 near Point Hope and another on 8 May 1978 near Point Barrow, engaging in a series of these exuberant activities for over 90 minutes each. Along with numerous flipper slaps, tail lobes, and lunges, the whale seen near Point Hope breached 57 times in 96 minutes.

It is not known why whales breach. Eskimo hunters on St. Lawrence Island say that breaching occurs more frequently when atmospheric pressure is dropping. Rugh and Cabbage (1980) report that such behavior might be related to display or communication. We observed a whale breaching and lobe-tailing on 8 May at Barrow. A whale from farther out in the lead moved close to the first animal, and the two swam together, cavorting on their backs and sides, often with a flipper exposed above the surface. We do not know if the whales were of the same sex, or if anything more than a social encounter occurred, but the activities of one whale seemed to attract the other's attention.

On several occasions we have seen groups of whales rolling laterally and breaching in a tight group. In May 1978 near Point Barrow, Smithhisler and Ed Iten of the NMFS National Marine Mammal Laboratory observed such behavior at close range. They, along with an Eskimo whaling crew⁸, observed four bowhead whales surfacing together for 15 minutes about 20 m away in a polynya approximately 50 × 100 m. The largest of the four whales was approximately 13 m long, the next was about 12 m, and the other two were about 10 m long. The whales breached and rolled laterally several times, often in unison. At times these whales grasped one another and rubbed each other with their flippers. All movements were slow, controlled, and quite graceful. Several times one of the smaller whales swam toward the edge of the ice, but each time the others pushed it

⁸R. Aiken, Barrow, AK 99723.



Figure 2. — Bowhead whale resting at the surface. White spot on back is believed to be ice or glare. Photographed by Bruce D. Krogman, Natl. Mar. Mammal Lab., NMFS, 13 June 1976.



Figure 3. — Breaching bowhead whale near Point Hope, Alaska. Note white chin patch. Photograph by Geoffrey Carroll, 18 May 1977.

back to the center of the polynya as they continued stroking, rolling, and showing their flukes as they dove. The largest whale exhaled with a controlled flatulent sound from its blowhole. It surfaced very high and swam backwards (behavior also reported by Bodfish, 1936), pushing itself up with its flippers and pulling down with its flukes, all the while making a low groaning sound. We assumed their be-

havior was associated with mating, but no obvious copulation was observed. The behavior of these whales was similar to the sexual behavior described by Everitt and Krogman (1979) (Fig. 4).

Feeding Behavior

Stomachs of bowheads harvested in the spring are generally empty or nearly empty, whereas stomachs of whales taken in the fall generally contain some



Figure 4.—Six bowhead whales engaged in sexual behavior near Point Barrow, Alaska. Photograph by Bruce D. Krogman, 8 May 1976 (from Everitt and Krogman, 1979).

food (Lowry et al., 1978; Marquette, 1978; Braham et al., 1979; Marquette, footnote 6). However, near Point Barrow in the spring of 1978, Jarrell⁹ observed what appeared to be feeding by a few bowheads. The whales made surface trawls, rostrums up and mouths open, and short dives, coming up breaching with their mouths open and water streaming out of the baleen.

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⁹G. Jarrell, Inst. Arctic Biol., Univ. Alaska, Fairbanks, AK 99701, pers. commun.

Sounds Recorded in the Presence of an Adult and Calf Bowhead Whale

D. K. LJUNGBLAD, S. LEATHERWOOD, and M. E. DAHLHEIM

Introduction

There is little information available on sounds produced by bowhead whales, *Balaena mysticetus*. Aldrich (1889) described their sounds (heard through the hull of his boat and therefore somewhat modified) as resembling "the hoo-oo-oo of the hoot-owl, although longer drawn out, and more of a humming sound than a hoot. Beginning on F, the tone may rise to G, A, B, and sometimes to C, before slanting back to F again."

Attempts have been made to record bowhead whale vocalizations, but when analyzed, most of the sounds recorded proved to be those of the bearded seal, *Erignathus barbatus*¹.

On 23 May 1978 near Point Barrow, Alaska, vocalizations attributed to an adult bowhead whale and/or an accompanying calf were recorded. This paper describes the circumstances surrounding the recording of these sounds and summarizes basic characteristics of the sounds.

Methods

Personnel of the National Marine Mammal Laboratory (NMML), National Marine Fisheries Service (NMFS), NOAA, Seattle, Wash., maintained spring ice camp census stations (North Camp and South Camp) along the nearshore lead off Point Barrow, Alaska, to count migrating bowhead whales. This census was conducted during the annual spring migration of the western Arctic population of bowhead whales from their wintering grounds in the Bering Sea to their summering grounds in the Beaufort Sea (Braham et al., 1979).

From 21 through 24 May 1978, we recorded underwater sounds at North Camp, approximate position lat. 71°28'N, long. 156°34'W. Sounds in the lead were monitored by a U.S. Navy (hydrophone) sonobuoy (AN/SSQ-41/A) modified to increase its frequency response to 40 kHz. The hydrophone was at a depth of 7 m. The signal was monitored by a 100 kHz bandwidth VHF receiver, Defense Electronics Instrumentation². The tape recorder (Nagra SJ) had a 40 kHz bandwidth.

Results

On the morning of 23 May 1978 the nearshore lead, which had been open to widths of up to nearly 7 km during the preceding 6 weeks, closed from just northeast of the camp to a distance of at least 10 km north. Although no whales were seen all morning, at 1250 hours sounds were audible, increasing in intensity for 10 minutes. At 1300 hours two bowhead whales were sighted, one estimated to be 13-15 m long and the other 4.5-6 m long. The whales surfaced in open water northwest of the camp at an estimated distance of 500 m. They approached to within 300 m of the hydrophone. Their relative sizes and closely coordinated movements led us to conclude that the two whales were an adult and calf.

During the 1-hour recording period (1250-1350 hours), 75 vocalizations were recorded. Of these, 33 were of sufficient intensity relative to background noise to be analyzed. Sounds were examined on a Spectral Dynamics real-time analyzer Model 301A, which provided a continuous cathode ray tube and paper display of frequency and relative amplitude level

as a function of time. Frequency content and signal duration were determined from these displays.

The sounds were of two basic types, designated A and B. Type A sounds (Fig. 1, Table 1) were 0.30-0.85 seconds in duration (average 0.58 seconds) and characterized by higher frequencies, particularly near their termination. These sounds occurred 18 times and ranged in frequency from 50 to 580 Hz, with the average lower frequency limit of 135 Hz and average higher frequency limit of 337 Hz. Typically, the analysis showed no well-defined harmonics.

In comparison, the 15 Type B sounds (Fig. 1, Table 2) were usually longer in duration, 0.65-2.56 seconds, with an average of 1.65 seconds, and characterized by a relatively constant frequency. Their fundamentals ranged from 100 to 195 Hz, with an average lower frequency limit of 140 Hz and an average higher frequency limit of 164 Hz. These sounds often had energy up to the seventh harmonic, and could be classified by their harmonic structures (Watkins, 1967).

Discussion

Several factors support our conclusion that these sounds were produced by bowhead whales. Most convincing was the change in relative intensity level as the whales were seen to move by our recording station. The sound level increased as the whales approached our hydrophone position and decreased as they moved away. It was not possible, however, to determine whether one type of sound was made by the adult whale and the other by the calf. The distinctive sounds of bearded seals (Ray et al., 1969) and ringed seals, *Phoca hispida*, (Stirling, 1973) recorded earlier in the week, were conspicuously absent on this day. This enabled us to obtain recordings of a quality suitable for analysis.

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¹W. A. Watkins, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, pers. commun. December 1978.

²References to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—List of Type A sounds produced by bowhead whale adult and calf; sounds are arranged in order of signal duration.

Duration of fundamental (sec)	Lowest frequency (Hz)	Highest frequency (Hz)	Fundamental	Harmonics						
				2	3	4	5	6	7	
0.30	60	220	X							
0.35	220	240	X							
0.4	150	170	X							
0.45	150	320	X							
0.45	120	380	X							
0.5	160	395	X							
0.5	160	300	X							
0.55	145	390	X							
0.55	150	410	X							
0.6	50	100	X							
0.6	140	350	X							
0.65	120	180	X							
0.7	155	195	X							
0.7	125	580	X	X						
0.75	130	360	X							
0.8	135	540	X							
0.8	150	580	X							
0.85	165	350	X							
Range	0.30-0.85 seconds	50-220 Hz								
Average	0.58 seconds	135 Hz								
										100-580 Hz 337 Hz

Table 2.—List of Type B sounds produced by bowhead whale adult and calf; sounds are arranged in order of signal duration.

Duration of fundamental (sec)	Lowest frequency (Hz)	Highest frequency (Hz)	Fundamental	Harmonics						
				2	3	4	5	6	7	
0.65	140	150	X							
1.2	120	160	X	X	X					
1.35	160	190	X	X	X	X	X	X		
1.45	100	120	X	X						
1.5	150	160	X	X	X					
1.55	140	150	X			X	X			
1.65	100	130	X							
1.65	120	150	X	X	X	X	X	X		
1.7	180	195	X	X	X	X				
1.75	150	180	X	X						
1.75	120	170	X	X	X	X	X	X		
1.85	125	150	X	X	X	X	X	X	X	
2.0	140	180	X	X	X	X	X			
2.1	180	190	X	X	X	X	X	X		
2.56	175	180	X	X						
Range	0.65-2.56 seconds		100-180 Hz							120-195 Hz
Average	1.65 seconds		140 Hz							164 Hz

Some similarities exist between the sounds we recorded and those of southern right whales, *Eubalaena glacialis* (Cummings et al., 1972). To study the similarities further, more data will be required.

During spring 1979, recordings were made by Naval Ocean Systems Center (NOSC) and NMFS personnel of sounds attributed to bowhead whales. Analysis of these recordings, now being undertaken at NOSC, San Diego, Calif., and Woods Hole Oceanographic Institution, Woods Hole, Mass., should provide more detailed information about sounds produced by this species.

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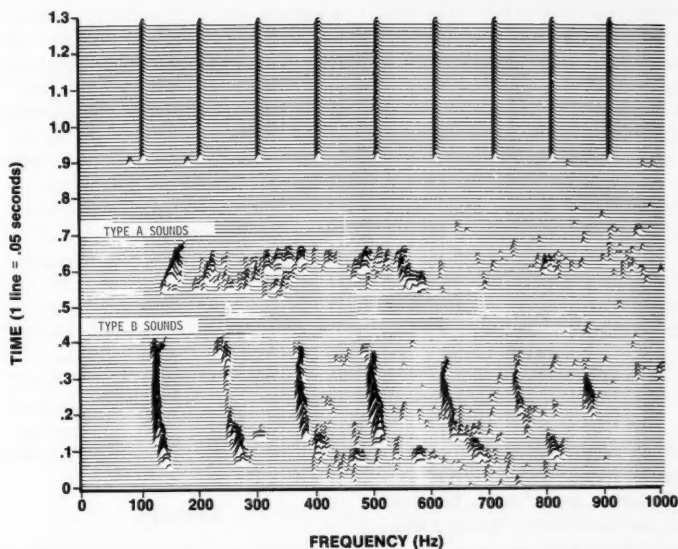


Figure 1.—Sample spectrograph of sounds produced by bowhead whale adult and calf.

Foods Utilized by Bowhead Whales Near Barter Island, Alaska, Autumn 1979

LLOYD F. LOWRY and JOHN J. BURNS

Introduction

Bowhead whales, *Balaena mysticetus*, spend the late spring, summer, and early autumn in the Beaufort Sea (Segeant and Hoek, 1974). On their northward spring migration they usually begin to pass Point Barrow, Alaska, in the latter part of April (Durham, 1979; Braham and Krogman¹; Marquette²). Their penetration of the spring ice sheet from the central Bering Sea is as much as 3,000 km (Tomilin, 1957). During September and October they again pass Point Barrow on their way into the Chukchi Sea, some at least having moved westward along the Alaskan coast (Braham and Krogman, footnote 1). The latest sighting of a bowhead near Point Barrow in the autumn, of which we are aware, was of one seen on 14 November 1977 (Burns, pers. obs.).

The Beaufort Sea is a region of great seasonal extremes. A cover of ice and snow largely prevents photosynthetic primary production for at least 4 months of the year. A brief period of open water occurs each summer, the duration and geographical extent of which vary greatly from year to year. In spite of such conditions, which would appear not to favor regular production of large plankton stocks, several species of animals, including the bowhead whale, use the Beaufort Sea as a summer-early autumn feeding area.

It is not known whether bowheads feed during winter while they are in the Bering Sea. They feed only little or not at all during their spring migration (Johnson et al., 1966; Marquette, footnote 2; Foote³). Intensive feeding occurs during summer and autumn in the eastern Arctic (Scoresby, 1820) and indeed in Alaskan waters the only whale stomachs which contained appreciable amounts of food have been taken during the autumn whaling season (Lowry et al., 1978). Large aggregations of bowheads, which appeared to be feeding, have been seen nearshore east of Point Barrow in September (Braham and Krogman, footnote 1; Burns, pers. obs.). Intensive feeding presumably occurs while the whales are in the Beaufort Sea. The quantities and kinds of available food in this region must be adequate to meet immediate bioenergetic requirements of whales and to provide reserves for periods of reduced feeding.

There are no published accounts of what foods are utilized by bowheads in the Beaufort Sea east of Point Barrow. We have recently acquired and examined samples of stomach contents from five of these animals taken between 20 September and 11 October 1979 near Barter Island, Alaska.

Methods

In the field, samples ranging in volume from about 200 to 2,500 ml were randomly collected from the whales' stomachs. From the whale designated as 79-KK-5, an additional nonrandom sample was taken which included primarily large, unusual appearing items. With the exception of

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whale 79-KK-1, which was recovered 2 days after it was struck, samples were collected within a few hours of the time the whale was killed and landed. Samples were labeled, preserved in a 10 percent Formalin⁴ solution, and delivered to Fairbanks, Alaska.

In the laboratory, a 100 ml aliquot of each sample was taken for possible future fatty acid content analysis. The remainder of the samples were drained and gently washed on a 1.00 mm mesh sieve. The stomach contents were then sorted macroscopically into major taxonomic groups, and the volume of each group was determined. The items in each group were examined microscopically when necessary and identified to species if possible. The number of individuals and total volume of each prey species were determined and the lengths of representative specimens were measured. In the case of abundant, small organisms such as copepods, the volume and number of the various species were estimated from subsamples.

Results

Based on the quantities and condition of the stomach contents, all five whales were feeding at the time they were killed. Estimated total volume of stomach contents varied from 19 to 45 l (5-12 gallons). A summary of the species present, approximate abundance in each sample, and those previously reported as food items in whales taken off northern Alaska are presented in Table 1. Copepods were found in all five samples and were the dominant food item in three. *Calanus hyperboreus* was by far the most commonly eaten species. The stomach contents of whale 79-KK-4 were in particularly good condition. In that whale most of the *C. hyperboreus* eaten were copepodid Stage V. Euphausiids, almost exclu-

¹Braham, H., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi, and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

²Marquette, W. M. 1977. The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-76, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

³Foote, D. C. 1964. Observations of the bowhead whale at Point Hope, Alaska. Unpubl. manuscript, 78 p. Geogr. Dep., McGill Univ., Montreal, Que., Can.

⁴Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Food items from bowhead whale stomach samples collected at Kaktovik, Barter Island, Alaska, September-October 1979.

Food item	Whale specimen number					Food item	Whale specimen number				
	79-KK-1	79-KK-2	79-KK-3	79-KK-4	79-KK-5		79-KK-1	79-KK-2	79-KK-3	79-KK-4	79-KK-5
Copepods						<i>Monoculoides</i> c.f. <i>M. schneideri</i>	—	—	X	X	—
<i>Calanus finmarchicus</i>	—	—	—	XX	—	<i>Munropsis</i> c.f. <i>M. typica</i>	—	—	X	—	—
<i>Calanus hyperboreus</i>	XXX	XXX	XX	XXX	XX	<i>Onisimus glacialis</i>	—	X	—	—	—
<i>Chiridius obtusifrons</i>	—	—	—	XX	—	<i>Onisimus litoralis</i>	X	—	—	—	—
<i>Heterorhabdus</i> sp.	—	XX	—	XX	—	<i>Rozinante fragilis</i> ¹	—	—	—	X	—
<i>Metridia lucens</i>	—	XX	—	XX	—	<i>Weyprechtia heulagini</i>	—	—	—	X	*
						Family Lysianassidae	X	—	—	—	—
Euphausiids						Shrimps					
<i>Thysanoessa raschii</i> ¹	—	XX	XXX	XX	XXX	<i>Eualus gaimardii</i>	—	—	—	X	—
<i>Thysanoessa inermis</i>	—	—	—	—	X	<i>Sabinea septemcarinata</i>	—	—	—	X	—
Mysids						Family Crangonidae	X	—	—	—	—
<i>Mysis litoralis</i>	—	XX	XX	—	XX	Unidentified	—	X	—	—	—
Hyperiid amphipods						Isopods					
<i>Hyperia medusarum</i>	—	X	—	—	—	<i>Saduria entomon</i>	—	—	—	—	X
<i>Hyperia</i> sp.	X	—	—	—	—						
<i>Parathemisto abyssorum</i> ¹	—	—	XX	—	—	Cumaceans					
<i>Parathemisto libellula</i> ¹	X	X	X	X	*	<i>Diastylis</i> sp.	—	—	—	X	—
Gammarid amphipods						Fishes					
<i>Acanthostephea behringensis</i> ¹	—	—	X	—	*	<i>Boreogadus saida</i>	—	X	—	—	*
<i>Acanthostephea incarinata</i>	—	X	—	—	—	<i>Myoxocephalus quadricornis</i>	—	—	X	—	*
<i>Apherusa glacialis</i>	—	—	—	X	—	<i>Pungitius pungitius</i>	—	—	—	—	*
<i>Aplys carinatus</i>	—	—	X	—	—	Unidentified	—	—	—	X	—
<i>Gammaracanthus loricatus</i>	—	—	X	—	*						
<i>Gammarus</i> sp. ¹	—	X	—	—	—	Pebbles	X	—	—	—	X

XXX = dominant item in sample.

XX = more than 10 individuals in sample.

X = 1-10 individuals in sample.

* = present in qualitative sample only.

¹Indicates previously reported food items of bowhead whales from northern Alaska (Lowry et al., 1978; Marquette, 1979).

sively *Thysanoessa raschii*, occurred in four samples and were dominant in two. *Mysis litoralis* was common in three samples. Although at least 22 other prey species were identified, none were major components of the food. The majority of identified species were amphipods, most of which are benthic forms.

A quantitative summary of the major prey types found in the samples is shown in Table 2. In addition to the proportion of each sample which was comprised of each prey type, an overall mean percentage of contents was calculated for each prey type based on the volume of subsamples, the proportion of prey types in the subsamples, and the estimated total contents of each stomach. Copepods and euphausiids in combination made up 91.2-99.7 percent of the contents of all subsamples. The relative importance of these two prey types varied markedly from over 99 percent copepods in whales 79-KK-1 and 79-KK-2, to almost 98 percent euphausiids in 79-KK-5. In the overall composition of the food, copepods were more important in terms of vol-

Table 2.—Quantitative composition of stomach contents from bowhead whales collected at Kaktovik, autumn 1979. For each whale, numbers indicate percent of the sample volume comprised of each prey type.

Prey type	Whale specimen number					Overall mean percent of contents ¹
	79-KK-1	79-KK-2	79-KK-3	79-KK-4	79-KK-5	
Copepod	99.7	99.0	23.4	88.3	<0.1	59.8
Euphausiid	—	0.3	67.8	4.9	97.9	37.2
Mysid	—	0.3	7.0	—	0.8	0.2
Hyperiid amphipod	<0.1	0.1	0.5	0.4	—	0.1
Gammarid amphipod	0.1	0.1	0.3	2.4	0.1	0.4
Other invertebrate	<0.1	<0.1	—	2.3	1.1	0.6
Fish	<0.1	0.1	1.0	1.7	—	0.4
Sample volume (ml)	2,406.2	545.2	399.7	131.3	357.9	
Estimated total volume of contents (gallons)	12	5	6	5	10	

¹The overall mean percent of contents was calculated based on the volume and percent composition of each sample and the estimated total contents of stomachs from which the samples were taken.

ume than were euphausiids. All other food types were insignificant in terms of overall volume consumed.

Discussion

The samples of stomach contents just described constitute the only data available on bowhead whale foods in the eastern portion of the Alaskan Beaufort Sea. Two whales taken at Barrow in September 1976 had eaten mostly euphausiids (Lowry et al., 1978). The principal euphausiid species (*Thysa-*

noessa raschii) found in whales taken at Kaktovik was the same as that found in the whales taken at Barrow. This species is widely distributed in Arctic waters (Geiger et al., 1968) and is of greatest abundance in the nearshore neritic zone (Nemoto, 1966). A whale taken at Barrow in May 1977 had eaten mainly copepods (Marquette, 1979). None of the copepod species eaten at Kaktovik were found in the whale taken at Barrow. This is particularly interesting since the main species eaten at

Barrow (*Calanus glacialis* and *Metridia longa*) and Kaktovik (*Calanus hyperboreus*) are all considered to be widely distributed in surface waters of the Arctic Ocean (Grainger, 1965). It is probable that copepods and euphausiids are, overall, the most important bowhead foods in the Beaufort Sea. Mysids and hyperiid amphipods also are concentrated in some regions and may be locally important foods.

A large number of prey species were identified from the Kaktovik whales. Mysids, isopods, and cumaceans were not found among the Barrow specimens. The only previous indication that fishes might be eaten by bowheads was a fish scale in specimen 77-B-5 (Marquette, 1979). Fishes representing three species were found in the whales taken at Kaktovik. In addition, at least 10 species of amphipods and 2 species of shrimp were first recorded as bowhead prey in these samples.

Although organisms such as gammarid amphipods, fishes, and isopods are apparently not major foods of bowheads in terms of quantities consumed, their presence in the stomach contents is of some significance. The presence of pebbles and bottom dwelling species indicates that all the whales taken at Kaktovik had fed at least partially near the sea floor. Pelagic prey far outnumbered the benthic organisms. Therefore, a feeding dive probably involves swimming obliquely from surface to bottom and back, feeding the entire time. *Saduria entomon* has not been found deeper than 44 m in the Beaufort Sea (McCrimmon and Bray, 1962). *Myoxocephalus quadricornis* and *Pungitius pungitius* are characteristic of coastal fresh and brackish water (Andriyashev, 1954; Walters, 1955). Therefore, at least whales 79-KK-3 and 79-KK-5 had fed in relatively shallow, nearshore waters.

Although exploration and development of Beaufort Sea hydrocarbon reserves are underway in Canadian waters and imminent off Alaska, the potential effects of such activities on foods of bowhead whales and food webs of the Beaufort Sea are impossible to predict at this time. The only major bowhead prey species which has been

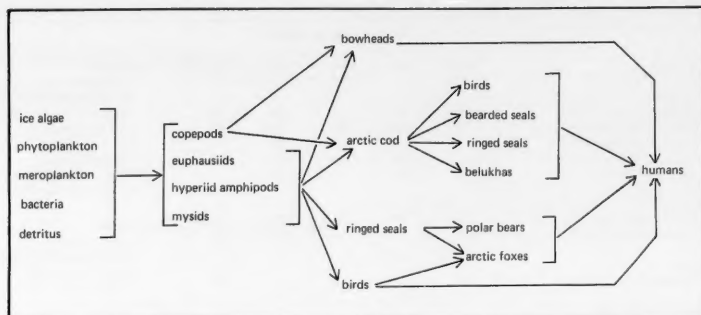


Figure 1. — Diagrammatic representation of major trophic connections in the pelagic food web of the western Beaufort Sea.

tested for hydrocarbon sensitivity is *Calanus hyperboreus*. This species was found to be "surprisingly resistant to all of the oils tested" (Percy and Mullin, 1975). Hydrocarbon sensitivity data for other key species in the Beaufort Sea food web such as other copepods; Arctic cod, *Boreogadus saida*; euphausiids; mysids; and hyperiid amphipods are urgently needed.

In the Alaskan Beaufort Sea, bowheads depend primarily on a pelagic food web (Fig. 1). Arctic cod feed primarily on copepods in offshore (greater than 40 m deep) waters during summer (Frost et al.⁵). During the summer, ringed seals, *Phoca hispida*, feed mostly on euphausiids, hyperiid amphipods, and mysids (Lowry et al.⁶, 1978). Ringed seals and Arctic cod are probably the most significant trophic competitors of bowhead whales in the Beaufort Sea. Changes in populations of these competing species, whether natural or caused by Alaska Outer Continental Shelf oil and gas

development activities, may affect the size and recovery rate of the bowhead population.

Acknowledgments

This study was part of Project Whales (Research Unit 280), completed by the Naval Arctic Research Laboratory, Barrow, Alaska. Project Whales was funded by the U.S. Bureau of Land Management/Outer Continental Shelf studies. T. Albert, University of Maryland, coordinated the acquisition of specimens and undertook field work to acquire some of them. G. Jarrell, M. Nerini, and D. Smullin, with the National Marine Fisheries Service, Seattle, Wash., also provided assistance—Jarrell and Smullin by obtaining some specimens at Barter Island and Nerini by transporting and making them available to us. Laboratory facilities were provided by the Alaska Department of Fish and Game, Fairbanks. We are indebted to G. Mueller, A. Adams, and K. Coyle, University of Alaska, Institute of Marine Sciences, for identification of copepods and amphipods. K. Frost, Alaska Department of Fish and Game, Fairbanks, provided invaluable assistance in all phases of this study. Our thanks are also extended to those whaling captains and crews at Barter Island who cooperated in this effort.

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Some Observations on Urine From a Bowhead Whale

W. MEDWAY

The analysis of urine is an essential part of any examination of an animal to determine its health status. This is true especially when (for purposes of comparison) there is a large store of data about urine of the species in question. The urine of the bowhead whale, *Balaena mysticetus*, has apparently not been examined.

On 18 May 1978 a urine sample identified as having originated from a bowhead whale, designated by the National Marine Fisheries Service as #78B2, was presented to this laboratory. The urine was obtained by cystocentesis from a male about 8.4 m in length, taken by Eskimo hunters on 2 May 1978 at Barrow, Alaska. The urine was refrigerated until 6 May, then frozen. On 15 May the frozen specimen was prepared for shipment. Unforeseen

delays during shipment allowed the urine to thaw by the time it reached this laboratory. Findings are presented here not only for general information but also as a small contribution to the data concerned with the biology of this endangered species.

Results and Discussion

On routine clinical urinalysis the following observations were made. The urine was dark amber, clear, and had no odor. The pH was 5.5, and the specific gravity (SG) was 1.032; there was a trace of protein; and the tests for ketones, glucose, reducing substances, bile pigments, hemoglobin, and urobilinogen were negative. Microscopic examination of the sediment revealed a few red and white cells, but no casts; however, there were myriads of epithelial cells (some were cornified), and there were some bladder transitional cells and caudate cells. There were many unidentified spheroid crystals (probably urates), and there were

Table 1.—Amino acid content of urine from a bowhead whale.

Amino acid	Nanomoles/mg creatinine
Threonine	31
Serine	28
Asparagine	99
Glutamine	32
Proline	64
Glutamic acid	11
Glycine	84
Alanine	43
α Amino adipic acid	14.5
α Amino-n-butyric acid	17
Valine	18
Half cystine	115
Cystathionine	25
Methionine	10
Isoleucine	Trace
Leucine	18
Tyrosine	29
Phenylalanine	10
Ornithine	Trace
Lysine	17
1-Methylhistidine	Trace
Histidine	16
3-Methylhistidine	Trace
Arginine	Trace
Trimethyl lysine	204
NN dimethylarginine	31
N'N dimethylarginine	24

also occasional oxalate crystals as well as a few triple phosphate crystals.

On further analysis the following results were obtained: Sodium ion 183 meq/l, potassium ion 14.4 meq/l, chloride ion 433 meq/l, osmolality 1,440 milliosmols/l, creatinine 400 mg/dl, urea N 3,000 mg/dl. The amino acid pattern obtained can be seen in Table 1 and is similar to that seen in adult mammals such as the dog. The

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amino acid determinations were made in a Beckman Amino Acid Analyzer.¹

While Hill, quoted by Laurie (1933), was correlating the pressure conditions in the lungs of blue whales, *Balaenoptera musculus*, with the gaseous nitrogen content of urine, he also measured the specific gravity of the urine on 13 occasions and the sodium chloride (NaCl) content 43 times. The SG ranged from 1.029 to 1.038 with a mean of 1.034; the NaCl content ranged from 13.33 to 26.60 mg/ml with a mean of 21.30 mg/ml. This is 360 meq/l for both sodium and chloride ions. In the present instance an SG of 1.032 on the bowhead whale urine and sodium ion=183 meq/l and chloride ion=433 meq/l were obtained. Furuhashi (1927) obtained a mean chloride ion value of 318 meq/l on eight samples: Three from fin whales, *B. physalus*; four from sei whales, *B.*

borealis; and one from a sperm whale, *Physeter macrocephalus*.

Laurie (1933) obtained chloride values on urine from blue and fin whales ranging from 120 to 455 mM/l with many values near the upper limits.

Löwenbach, quoted by Krogh (1939), obtained chloride values ranging from 75 to 820 mM/l (mainly on *Megaptera boops*)². He stated that the usual range is between 280 and 520 mM/l. Schmidt-Nielsen and Holmsen (1921) obtained values of 266 mM/l and 362 mM/l of sodium and chloride, respectively, on urine from both crustacean-eating whales, *B. borealis*, and from mainly fish-eating whales, *B. physalus*. They also reported on the examination of fresh urine from one *B. borealis* that had a specific gravity of 1.027 and a freezing point depression of -2.46°C . This represents an osmolal-

ity of 1,323 mo/l. The chloride ion content of this urine was 181 meq/l.

Acknowledgments

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¹Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

²Present scientific name is *Megaptera novaeangliae*.

Healed Penetrating Injury of a Bowhead Whale

THOMAS F. ALBERT, GEORGE MIGAKI, HAROLD W. CASEY, and L. MICHAEL PHILO

The bowhead whale has been successfully hunted by the Eskimos of Arctic Alaska for centuries. In recent years increasing concern has been expressed over the rising number of animals taken or struck and lost (Marquette, 1979). The fate of those that are struck and lost is not known; however, it is reasonable to assume that many succumb to their wounds.

An instance of a bowhead whale evidencing a healed penetrating injury is described in this report. Although positive proof is lacking, a reasonable explanation is that the penetration was due either to a harpoon or a bomb fired

from a shoulder gun. The whale was taken during the fall 1978 whaling season in the Beaufort Sea off Kaktovik, Barter Island, on the northeastern coast of Arctic Alaska. The animal was struck on 15 September 1978 and lost in an approaching storm. On 21 September, with aircraft support, the animal was found floating approximately 28 km to the west and 4 km from shore. The whalers then beached the animal at that point.

The animal was a male, approximately 10.6 m in length, and was designated as whale #78KK1 by the National Marine Fisheries Service. As the

butchering proceeded, large sections (approximately 0.9 m \times 0.6 m \times 0.2 m) of skin with underlying blubber were removed and placed upon the beach. During collection of tissue specimens from the sections, what appeared to be a scar was noted extending from the skin and through the blubber. The area of suspected scar tissue was a whitish tract that extended through the blubber at an angle; it was 2.5 cm in diameter, 11 cm long, and firmer than the surrounding blubber (Fig. 1). The whitish tract in the blubber, hypodermis, and dermis was continuous externally with an area of white skin, slightly

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Figure 1. — Large section of skin with attached blubber. Note locus of white epidermis with scar tissue (closed triangles) extending through blubber.

depressed from the surrounding black skin. This locus of white skin was somewhat irregular in shape, approximately 2.5 cm long, 1 cm wide, and 0.8 cm thick. Since the suspected scar was noticed in tissue removed from the animal it was neither possible to localize its position upon the animal nor to determine the full extent of the penetration. This and other materials were placed into 10 percent buffered Formalin¹ and prepared for histological examination.

Histological Findings and Discussion

The epidermis of cetaceans is divided into three separate layers or strata (Harrison and Thurley, 1974). The stratum germinativum or the basal cell layer forms the junction between the dermis and epidermis and is comprised of columnar-type epithelial cells and melanocytes containing brownish-black melanin pigments. The presence of these pigments accounts for the black appearance of the skin. The stratum externum or the outer cell layer is comprised of flattened cells each containing

an elongated nucleus. Because all of the cells in the epidermis contain a nucleus, no true stratum corneum is recognized.

The normal skin of this bowhead whale was comprised of a thick epidermis and a relatively thin dermis which merged with a thick underlying hypodermis or blubber. The epidermis was black and about 18 mm thick. The rete ridges were uniform in size and shape and extended deep into the dermis. The dermal papillae containing small blood vessels were found more than half way up the epidermis (Fig. 2). The dermal papillae were comparatively wide; this would account for the visible parallel vertical lines which resulted in the striated appearance of the epidermis on the cut surface (Fig. 3).

The dermis measured about 3 mm in thickness and was comprised almost entirely of collagenous fibers with lesser

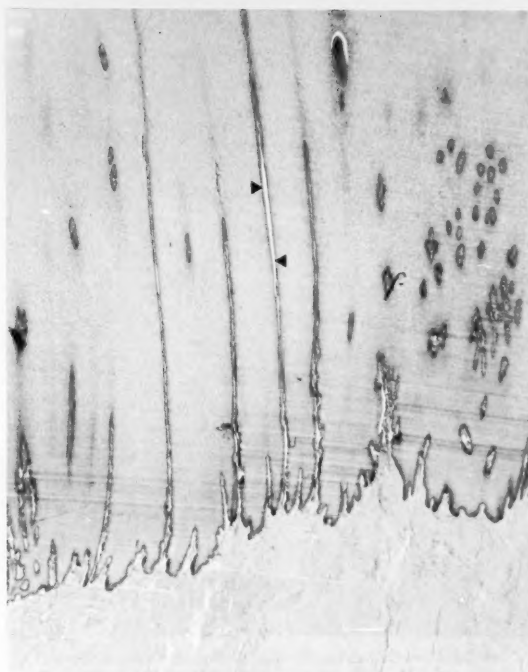


Figure 2. — Photomicrograph of skin with epidermis above and dermis below. Note dermal papillae (closed triangles) extending well into the epidermis. Hematoxylin and eosin; $\times 11$. Armed Forces Institute of Pathology photograph.

amounts of elastic fibers. The dermis was divided into an outer papillary layer containing the dermal papillae and an inner reticular layer which merged with the hypodermis. The fibers were arranged in bundles of uniform size and could be found extending in different directions, especially in the reticular layer. Blood and lymph vessels as well as nerve bundles were evident.

The blubber was continuous with the dermis and was comprised almost entirely of mature fat cells which were supported by thin bundles of collagenous fibers.

Histologically, some differences were noted between the white epidermis external to the fibrous tract and the adjacent black epidermis (Fig. 4). In this white epidermis, the cells did not contain melanin pigments and the rete ridges were very irregular in shape and

¹Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.



Figure 3. — Cut surface of skin with underlying blubber (A). Note vertical striations in black epidermis due to dermal papillae. Armed Forces Institute of Pathology photograph.

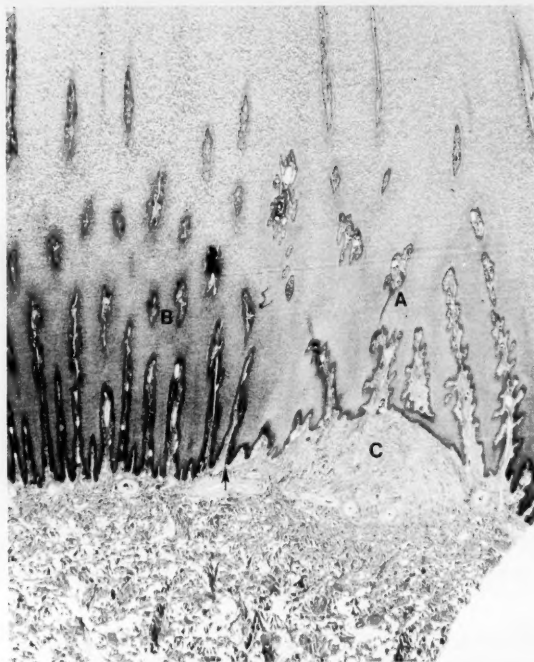


Figure 4. — Photomicrograph of skin at the junction (arrow) between white epidermis (A) and black epidermis (B). Note discrete areas of fibrosis in the dermis (C). Hematoxylin and eosin; $\times 11$. Armed Forces Institute of Pathology photograph.

appeared to be much wider and shorter (Fig. 5) than those of the black epidermis (Fig. 6). In the dermis beneath the white epidermis, the whitish tract was comprised of mature collagenous fibers arranged haphazardly and in smaller bundles (Fig. 7) than those seen in the normal dermis (Fig. 8). Evidence of granulation tissue was lacking and occasional foci of mononuclear leukocytic infiltrate were noted (Fig. 9). In the blubber the whitish tract was comprised of mature collagenous fibers arranged in bundles which were oriented in many different directions (Fig. 10).

The fact that the animal's skin was in contact with near freezing water undoubtedly contributed to the maintenance of the skin's histological structure following death.

The morphology of the white epidermis and the discrete whitish masses in the dermis and blubber are

suggestive of repair following a deep penetrating traumatic wound. The presence of mature collagenous tissue with little or no leukocytic response and the absence of vascularity are indicative of a chronic lesion of long duration. It is apparent that melanocytes were destroyed in the injured epidermis and that regeneration was accomplished by epithelial cells, thus resulting in a white epidermis.

White scars on the skin of cetaceans have been reported as resulting from various causes (Greenwood et al., 1974; Harrison and Thurley, 1974; McCann, 1974). These include mechanical pressure necrosis of the skin resulting from nonaquatic transportation, intraspecific fighting, attack by the sea lamprey, trauma due to contact with ice floes, and freeze branding. It has been noted, however, that the skin of cetaceans inhabiting cold northern waters is gener-

ally without scars (Yablokov et al., 1972).

Penetrating injuries containing portions of the spearlike snout of a swordfish (Machida, 1970) and marlin, *Makaira* sp. (Ohsumi, 1973), have been noted in at least the sei whale, *Balaenoptera borealis*, and minke whale, *Balaenoptera acutorostrata*.

In the present instance it is not likely that the penetrating injury was due to a billfish, as their distribution (Klawe, 1977) does not overlap with what is suspected to be the southern limit of the bowhead whale's range. It would also seem unlikely that the wound was due to a pointed object that the animal encountered in the water during its travels. A reasonable explanation is that the animal had been struck by an Eskimo hunter during an earlier whaling season and survived the encounter. As can be seen in Figure 11, the wound in

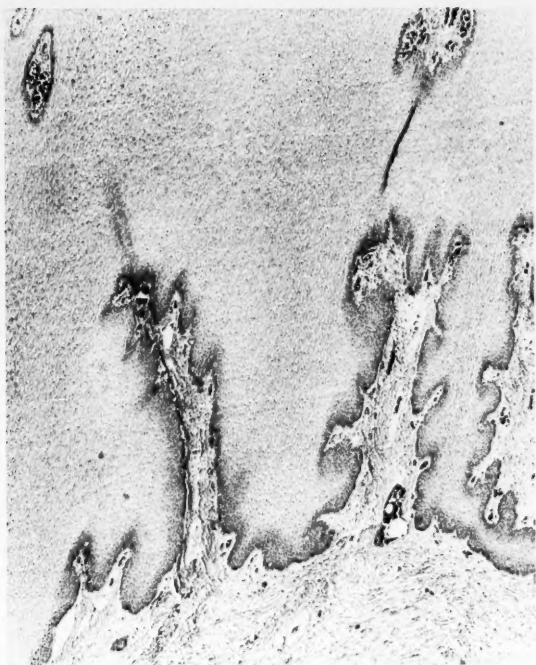


Figure 5.—Photomicrograph of the white epidermis. Note the absence of melanin pigment, and the irregularly shaped and short blunt appearance of the rete ridges extending into the dermis below when compared with the normal black epidermis in Figure 6. Hematoxylin and eosin; $\times 45$. Armed Forces Institute of Pathology photograph.

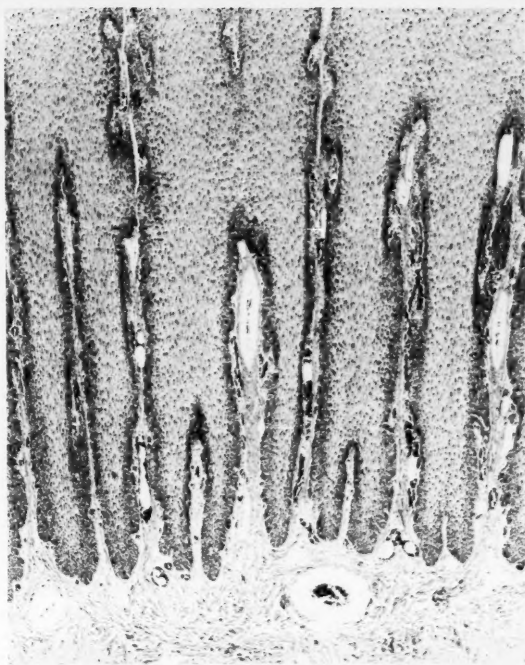


Figure 6.—For comparison with Figure 5. Photomicrograph of the normal black epidermis. Note the presence of melanin pigments and the uniform size and shape of the rete ridges extending into the dermis below. Hematoxylin and eosin; $\times 45$. Armed Forces Institute of Pathology photograph.

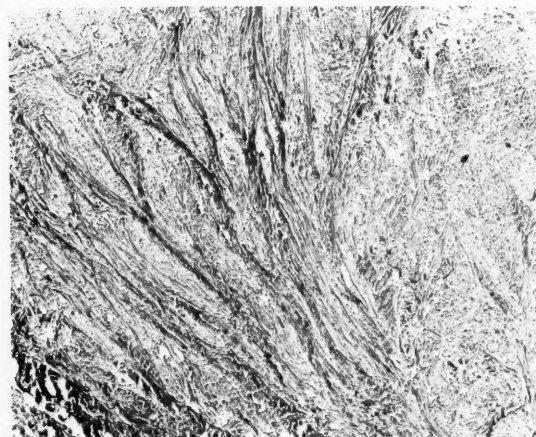


Figure 7.—Photomicrograph of the whitish tract in the dermis and blubber. Note the haphazard arrangement of the collagenous fibers which appear to be in smaller bundles than those found in the normal dermis (see Fig. 8). Mason trichrome; $\times 45$. Armed Forces Institute of Pathology photograph.

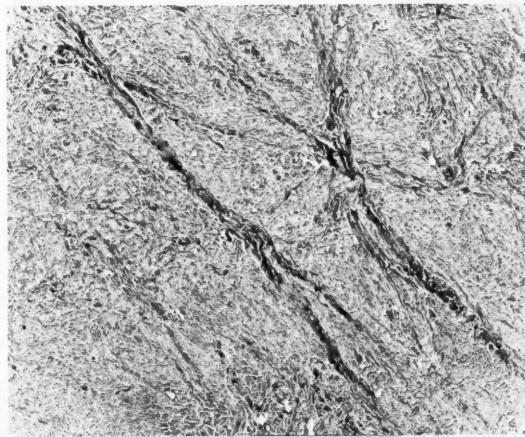


Figure 8.—For comparison with Figure 7. Photomicrograph of the normal dermis. Note the uniform size and appearance of the bundles of collagenous fibers. Mason trichrome; $\times 45$. Armed Forces Institute of Pathology photograph.

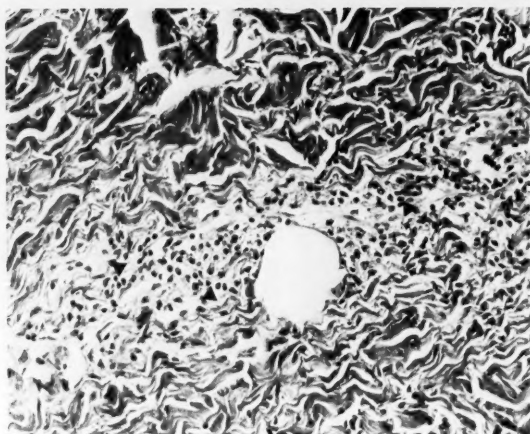


Figure 9.—Photomicrograph of the dermis beneath the white epidermis showing small foci (closed triangles) of lymphocytes and plasma cells. Hematoxylin and eosin; $\times 288$. Armed Forces Institute of Pathology photograph.

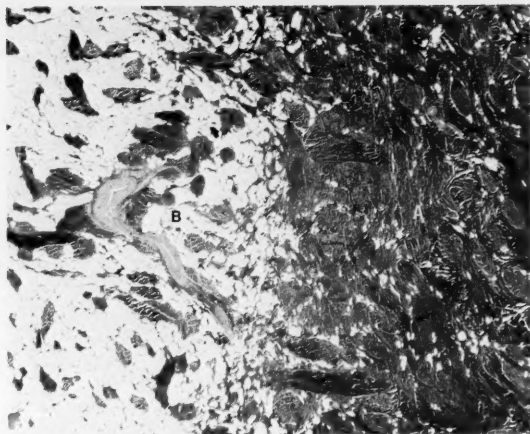


Figure 10.—Photomicrograph of the whitish tract (A) in the blubber (B). The whitish tract is composed almost entirely of mature collagenous fibers arranged in bundles. The blubber is largely composed of mature fat cells supported by thin bundles of collagenous fibers. Hematoxylin and eosin; $\times 11$. Armed Forces Institute of Pathology photograph.

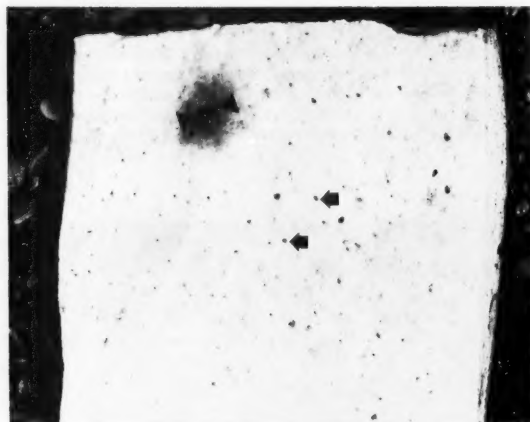


Figure 11.—Large piece of blubber lying on beach. Note fresh wound (closed triangle) caused by passage of one of the bombs used to kill the whale. Also apparent are numerous readily visible blood vessels (arrows).

the blubber caused by the passage of one of the bombs used to kill the animal is approximately the same diameter as that of the scar described above.

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Editorial Guidelines for *Marine Fisheries Review*

Marine Fisheries Review publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

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Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

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Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and

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In style, *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 6, "A List of Common and Scientific Names of Fishes from the United States and Canada," third edition, 1970. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

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Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

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All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8- × 10- inches, sharply focused glossies of strong contrast. Potential cover photos are welcome but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

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